DEPARTMENT OF DEFENSE
OFFICE OF GENERAL COUNSEL
1600 DEFENSE PENTAGON
WASHINGTON, DC 20301-1600

31 MAY 2001

Honorable Dan Burton
Committee on Government Reform
U.S. House of Representatives
Washington, D.C. 20515-6149

Dear Mr. Chairman:

This responds to the request from Subcommittee Chairman Christopher Shays for the August 2000 Report in Support of the National Missile Defense Deployment Readiness Review as prepared by the former Director, Operational Test and Evaluation, Mr. Philip Coyle.

The attached report is provided by the Department of Defense as a matter of discretion for use by the committee for its oversight purposes only. The Department of Defense has not approved the release of this report to the general public. Accordingly, the report should not be disclosed to persons other than Members of Congress and professional staff members who have an official need to see it. We specifically request that you not post this report on any web sites. This discretionary release in response to your request for this particular report does not waive any privilege and it does not constitute a public release.

Additionally, the discretionary release of this report should not be construed as a waiver of any future exercise of executive privilege or any other lawful grounds to deny release of reports of this nature.

If you have any questions, please feel free to contact Colonel Don Curry in Legislative Affairs at (703) 695-4132.

Sincerely,

Stewart F. Aly

Stewart F. Aly
Acting Deputy General Counsel
(Legal Counsel)

Copy Furnished:
Ranking Member, Committee on Government Reform
Chairman, House Committee on Armed Services
Ranking Member, House Committee on Armed Services
Chairman, Senate Committee on Armed Services
Ranking Member, Senate Committee on Armed Services

DIRECTOR

OPERATIONAL TEST AND EVALUATION

REPORT IN SUPPORT OF

NATIONAL MISSILE DEFENSE
DEPLOYMENT READINESS REVIEW

10 August 2000

I. INTRODUCTION

The Department of Defense Deployment Readiness Review (DRR) for National Missile Defense (NMD) will recommend to the President whether to begin the process of deploying an initial capability to defend all fifty of the United States against limited attacks from "states of concern"[1] or from accidental or unauthorized launches.[2] A decision to move toward deployment will permit site preparation for an X-band radar in Shemya, Alaska; construction schedules call for this decision by November 2000 if an operational capability is to be ready by 2005.[3]

This report provides an independent assessment of the NMD system's potential operational effectiveness and suitability at this time. Since NMD is still early in its development process, the data available for this assessment is limited, particularly at the system level. There also have been development delays, planned simulations were not available, and several important test events have slipped beyond the DRR. Also, it is unusual for a major defense acquisition program to be placing emphasis on a deployment decision based on limited data four or more years before the scheduled *start* of Initial Operational Test and Evaluation (IOT&E). We recognize that we are making our assessment of operational effectiveness before the system has completed development, and we expect our assessment will change as the system evolves.

The Ballistic Missile Defense Organization (BMDO) has defined – and OSD has approved[4] – seven Deployment Readiness Criteria for this DRR. These criteria address the potential of the NMD design and technology to meet the User's operational requirements, the ability to manufacture, field and sustain the initial system and, lastly, its affordability. This report focuses on the three criteria related to operational effectiveness

---

1 Formerly referred to as rogue states.

2 NMD ORD Revision (Approved 27 June 2000).

3 A DAB is planned for FY 2001 to authorize upgrades to Early Warning Radars and to build the XBR. A DAB in FY 2003 will authorize procurement and deployment of the interceptors.

4 The NMD deployment readiness criteria were approved by the Under Secretary of Defense (Acquisition & Technology) in June 1999.

and suitability,[5] and our assessment is made relative to the threshold ORD requirements for the initial increment of the NMD system called Capability 1 or C1. In addition to assessing how well the criteria have been demonstrated from a technical standpoint, this report also addresses the impact of test limitations and NMD Program evolution on the operational utility of a system to be deployed by 2005. We make only minimal comment on the criteria addressing manufacturing, contractual readiness, and affordability.

This report draws on data from the Integrated Flight Tests, Integrated Ground Tests, and exercises at the Joint National Test Facility (JNTF). We also draw on developmental test data at the element level, such as radar data gathered in Risk Reduction Flights, to the very limited extent that it is available. We have reviewed products from both the Lead System Integrator (LSI) and the joint Operational Test Agency (OTA) team, have monitored tests and exercises, and have attended design review and test analysis meetings. A complete listing of data products used is given in Appendix B.

---

5 Traditionally, operational assessments address the Critical Operational Issues (COIs) listed in the Test and Evaluation Master Plan (TEMP). A crosswalk (see Appendix A) between the OSD approved Deployment Readiness Criteria and the COIs defined in Part IV of the TEMP indicates that the criteria pertaining to operational effectiveness and suitability generally span the space defined by the COIs, with one major exception. The Deployment Readiness Criteria do not explicitly address system survivability and security (COI-5); Criterion 6 (Capability to Sustain the System) could be broadly interpreted to cover this area.

II. SUMMARY

The NMD system has partially fulfilled the three Deployment Readiness Criteria relating to operational performance, a finding based on the results from ground and integrated flight testing conducted to date. The NMD program has experienced significant delays in development and testing. Unless the program is restructured, the proposed deployment schedule is not likely to be realized. Also, the operational role of the limited system that might be initially deployed is still evolving. Lastly, the NMD Program has not yet developed a plan for growing the initial C1 capability to the full objective system.

A. DEMONSTRATION OF DEPLOYMENT READINESS CRITERIA

Criterion #1: "Demonstration of integrated system/element level functions through integrated ground and flight test, including two intercepts...of which one must be an integrated system test. To protect the FY05 IOC, a single intercept allows award of construction contracts (but not the start of construction), long haul communications, and approval of necessary long lead hardware."[6]

This criterion has not been fully met since the NMD system has not achieved two intercepts nor demonstrated integrated system performance with a successful intercept. It did achieve an intercept in IFT-3, which permits the award of construction contracts and acquisition of long lead hardware to protect the FY05 IOC. Furthermore, a significant, but not complete, degree of system functionality has been demonstrated with prototypes and surrogates. In each test, new functionality has been demonstrated in one element or another, and the program intends to integrate new performance features as it moves forward. The successful intercept was achieved in a test focused on demonstrating hit-to-kill and was not in an integrated system test with all the system elements represented.

---

6 Briefing by BG Willie Nance, *NMD Decision Criteria*, 11 June 1999. Criteria approved by USD(A&T), 23 June 1999.

The demonstrations of system functionality have significant caveats associated with them, including reliance on surrogate elements and range assets, e.g., GPS and/or the FPQ-14 range radar for engagement planning including Weapon Task Plan generation. Also, the scope of the threat presented in the flight tests was limited. Chapter V discusses this area in more detail.

Criterion #2: "An assessment of the ability of NMD system design to meet system performance requirements as specified in the NMD ORD." The assessment addresses four Key Performance Parameters (KPPs):

1. **Defense of the United States (at ORD specified levels)**
2. **Human-in-Control**
3. **Automated BMC3**
4. **Interoperability**

The NMD system's ability to defend all fifty states from attacks at ORD-specified levels (KPP #1) can not be satisfactorily assessed, primarily because the simulations that were to demonstrate this with confidence and high fidelity have not developed as planned.

Integrated Ground Tests (IGTs), using the computer processor-in-the-loop Integrated System Test Capability (ISTC) simulation, were to provide operationally realistic data on 13 "design-to" scenarios. A high fidelity digital simulation, the LSI Integration Distributed Simulation (LIDS), was to have been used by the contractor and OTA team to perform analysis of an even broader set of scenarios to demonstrate that the entire United States would be adequately defended. The ISTC proved to be too immature to provide reliable estimates of performance, and the development of the digital simulation, LIDS, is behind schedule and was not available to support analyses of overall system performance as originally intended.

Battle Planning Exercises and C2Sims show that the system has demonstrated satisfactory progress in meeting two of the four required KPPs, namely, Human-in-Control and automated BMC3. Demonstration of the interoperability KPP has not yet begun.[7] Refer to Chapter V for more details.

---

7 The approved ORD of January 1997 had only KPPs 1 – 3. The addition of the interoperability KPP was raised in 1999 but was not formally added until the new June 2000 ORD was approved. Assessing interoperability was not part of the LSI evaluation plan for the DRR.

Criterion #3: Maturity of the deployable system design, including the potential to evolve to counter more sophisticated threats.

Design reviews have not identified any significant issues pertaining to the maturity of the design of the NMD system or elements. However, the ability to perform a credible assessment of NMD design maturity is confounded by the current immature state of ground test facilities and models and simulations. Furthermore, the JPO has not yet developed a formal, credible plan for evolving the design from C1 to C2/C3. In particular, the ability to discriminate more sophisticated countermeasures needs special consideration.

Discrimination is a technical challenge for the hit-to-kill NMD system and a cause of concern regarding the potential of the C1 system to evolve to an effective C2 and C3 capability. The program has presented analysis and simulation results that indicate that techniques to discriminate unsophisticated countermeasures are in hand. However, the target suites flown in the three intercept tests to date included only two objects – an RV and a large balloon – and the EKV was required to discriminate the RV from only the large balloon and deployment bus, objects with signatures very dissimilar to the RV.[8] The EKV did successfully discriminate in IFT-3, but this demonstration is modest relative to the C1 threat space of unsophisticated countermeasures. Tests using balloons that match elements of the RV's signature begin with IFT- 9, scheduled for late FY 2002. The present lack of a high fidelity hardware-in-the-loop facility precludes convincing demonstrations of discrimination against the broader set of unsophisticated countermeasures, except in flight test.

Evolution of the C1 system to counter more sophisticated countermeasures has not been described by the NMD program in detail. We are unaware of any significant simulation efforts that address the issue of meeting C2 performance levels using either the EKV alone or with the discrimination capability of the radar. In addition, the current C1 test program does not consider other simple unsophisticated countermeasures – those falling outside the strict definition of "unsophisticated" yet seemingly simple to implement, e.g., tumbling RVs and non-spherical balloons.

---

8 The deployment process can create incidental debris in addition to the objects intentionally deployed. On IFT-5, the large balloon was carried but apparently did not deploy.

B. OPERATIONAL SCOPE

Over the recent course of the development program, the intended operational role of an NMD system has been defined in different ways. These differences are reflected in inconsistencies in requirements documentation and, thus, there is some ambiguity as to what is really desired.

The NMD Program transitioned from a technology readiness program to a Major Defense Acquisition Program in 1996. The 1997 BMDO Report to Congress (RTC) stated the objective of the system "to defend the United States from an emerging Rest-of-World (ROW) rogue state ballistic missile threat or against a limited or unauthorized missile launch."[9] That Report also stated that:

> The intelligence community has concluded that no country, *other than the major declared nuclear powers*, will develop or otherwise acquire a ballistic missile in the next 15 years that could threaten the contiguous 48 states; only a North Korean missile in development, the Taepo Dong 2, could conceivably have sufficient range to strike portions of Alaska or the far-western Hawaiian Islands, but the likelihood of it being operational within five years is very low. [italics added]
>
> – 1997 BMDO Report to Congress, Page 3-3

Consistent with this threat estimate, thirteen "design-to" scenarios were developed that included both ROW threats and accidental or unauthorized launches by established nuclear powers. Only four of the thirteen scenarios posited launches by ROW or rogue states; the rest postulated accidental or unauthorized launches by the major declared nuclear powers, including launches at targets on the East Coast. The thirteen design-to scenarios assumed unsophisticated countermeasures only.

The NMD Program's focus appears to have shifted to the threat posed by North Korea with the accidental/unauthorized threat becoming a secondary consideration. The recently issued Defense Planning Guidance Update FY 2002-2007 goes further, defining the purpose of NMD in terms of only rogue nations. The recently revised NMD ORD continues to mention accidental and unauthorized launches prominently. DoD and BMDO leadership have identified a limited missile attack from states of concern as a primary threat while continuing to mention some "residual" capability to defend against

---

9 RTC, page 3-1

the possibility of an unauthorized or accidental launch of more sophisticated threats.[10] Thus, there is some ambiguity in the operational requirements, particularly in defining the nature of the residual capability expected from NMD.

Contractually, the LSI contractor is required to deliver a C1 Capability that is effective against threats that deploy only "unsophisticated" countermeasures; this has not changed since the contract's inception. It is now recognized that accidental or unauthorized launches could employ countermeasures that would be considered sophisticated according to the definition in the LSI contract. A more aggressive program to complete the evaluation of C1 performance against unsophisticated countermeasures and to explore the technology to address more sophisticated countermeasures would better define the residual capability and move development toward realizing a C2 capability.

C. SCHEDULE ISSUES

Since the program was restructured in January 1999, the NMD program has experienced numerous program development delays, while the construction and production schedules have not slipped. To the program's credit, the flight test program has been event driven, with tests conducted only when the Program Office felt ready. As a result, IFT-3 was conducted 18 months behind the original 1996 schedule and four months behind the 1999 schedule. More recently, as illustrated in Figure II-1, additional significant test slips have occurred since the January 1999 program restructure. In particular, IFT-5 was to be conducted about six months before a June 2000 DRR but was actually executed on 8 July. This forced the DRR to be moved to August 2000. IFT-6, which had also been planned to precede the DRR, is expected to occur in January or February 2001.

---

10 For example, on February 2, 1999, the Secretary of Defense stated: "The primary mission of the NMD system being developed is the defense of the U.S. – all 50 states – against a limited strategic ballistic missile attack such as could be posed by a rogue nation. Such a system also would provide some capability against a small accidental or unauthorized launch of strategic ballistic missiles from more nuclear-capable states."

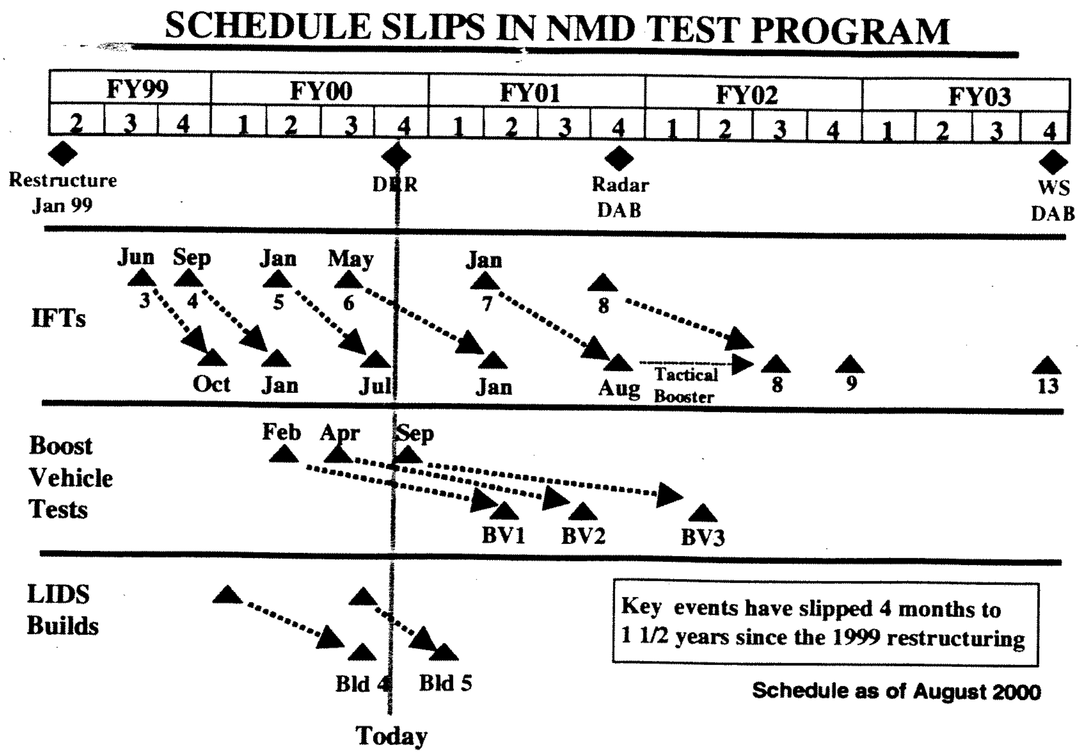

Figure II-1. Schedule Slips in the NMD Test Program

Development delays have already caused schedule slips of flight tests of the tactical booster to beyond the DRR. Boost Vehicle (BV) test #1 was originally scheduled for February 2000, then July 2000, and now second quarter of FY01. BV2 has slipped about a year. BV3, the first test to integrate the EKV with the booster, is behind about a year and a half. Additionally, the first use of the operational booster stack in an intercept test will now occur in IFT-8, vice IFT-7 as originally planned. As a result, the authorization of long lead acquisition for the Capability 1 (C1) interceptor system will have to be delayed commensurate with that testing.

Delays in the flight test program are the most visible, but developmental problems in simulation and ground test facilities may have an even greater impact. Since the flight test scenarios are severely constrained, ground testing and simulation are critical to evaluating system performance and the fulfillment of ORD requirements. The shortfalls in ISTC and delays in the LIDS delivery have already been mentioned.

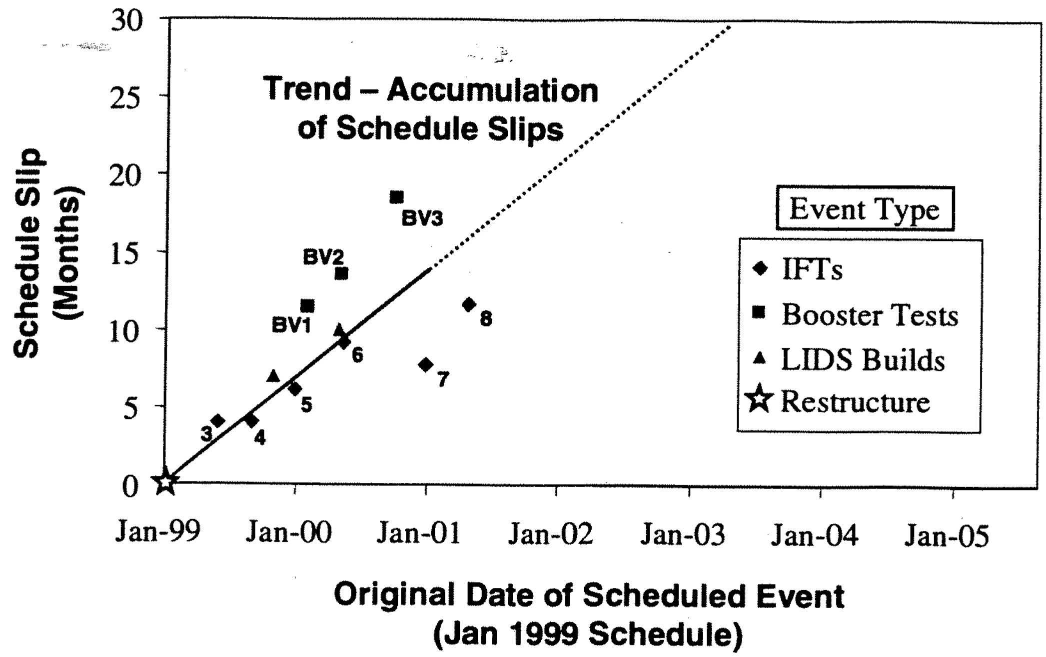

Figure II-2. Accumulation of Slips in Test and Development Schedule

Unless these trends are reversed, an IOC in FY05 appears unlikely. Figure II-2 illustrates the trend of development schedule slips and estimates schedules slipping at a rate of 20 months every three years. If these trends persist and efforts by the NMD Joint Program Office (JPO) to "buy back" schedule are unsuccessful, the first flight test with a production representative interceptor (IFT-13), scheduled for the first quarter of FY03, would slip about two years.

III. PROGRAM OVERVIEW

A. SYSTEM DESCRIPTION

The National Missile Defense (NMD) system has the mission of defending the entire United States against strategic ballistic missile attacks. The initial deployment capability, C1, is intended to defend against deliberate attacks by adversaries from states of concern and, to a lesser extent, limited accidental or unauthorized launches from the established nuclear-capable states. The C1 system is designed to meet the User's *threshold* effectiveness requirements, in terms of attack size and sophistication of countermeasures, and is the architecture under review at the Deployment Readiness Review. Key NMD system design concepts include:

- The NMD system is sized for limited attacks.
- The NMD system employs the hit-to-kill intercept concept; i.e., the threat is destroyed by force of impact.
- The NMD C1 system design will be constrained to a single weapons site.
- The NMD C1 system design is a ground-based system. Space-based sensors provide warning and cueing only.

The NMD program is expected to evolve from C1 in two phases to meet the system's *objective* effectiveness requirements. This will be accomplished by enhancing sensors and weapons, adding a constellation of low-orbit satellites (SBIRS-low), and increasing the number of radars, interceptors, and interceptor fields. The objective NMD system is referred to as Capability 3.

The NMD system is an integrated collection of "elements" that perform surveillance, detection, tracking, discrimination, and battle management functions, including engagement planning, intercept, and kill assessment. As depicted in Figure III-1, the NMD C1 system consists of the following elements:

- Battle Management, Command, Control, and Communications (BMC3)
- Weapon system: Ground Based Interceptors (GBIs) and support subsystems

- Space-based sensors: Defense Support Program (DSP) and high-orbit Space Based Infrared System (SBIRS-GEO/HEO) satellites
- Ground-based sensors: Five Upgraded Early Warning Radars (UEWRs) and one X-Band Radar (XBR)

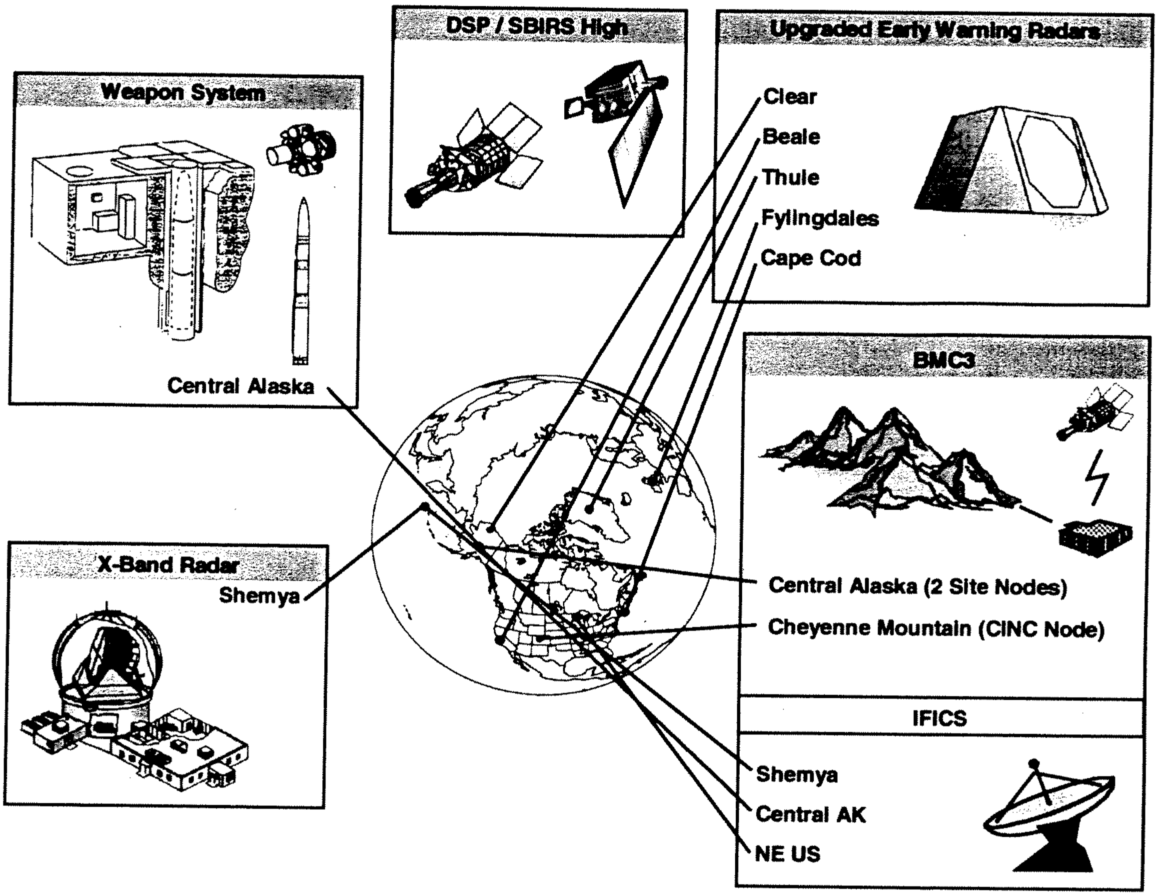

Figure III-1. NMD System C1 Architecture

1. Battle Management, Command, Control, and Communications

The BMC3 integrates and processes data from space-based and ground-based sensors to perform engagement planning, situation awareness, and decision support functions while maintaining a "human-in-control." It consists of the following principal subsystems:

- Battle Management, Command, and Control (BMC2) performs command and control, engagement planning, tasking, and situational awareness.
- NMD Communications Network provides the communication links between the individual NMD elements and external systems.

- In Flight Interceptor Communications System (IFICS) enables the BMC3 to communicate with the interceptor while in flight. For example, target data are uplinked to the kill vehicle through the IFICS to reduce and correct errors in targeting estimates.

2. Weapon System

The Weapon System consists of Ground Based Interceptors and supporting subsystems. The interceptor is a silo-based, three-stage missile with a separating Exoatmospheric Kill Vehicle (EKV) that engages the threat above the atmosphere, well in excess of 100 kilometers. The kill vehicle employs visible and infrared sensors to acquire and track the target, performs onboard discrimination to select the reentry vehicle (RV) from associated objects, and fires divert thrusters to steer the vehicle to achieve a direct hit on the RV.

3. Space-Based Sensors

The NMD system relies on the constellation of early warning satellites to detect launches of enemy missiles and to track them during their boost phases. The NMD C1 space component will consist of a combination of existing DSP satellites as well as SBIRS High satellites yet to be deployed. The Mission Control Station is the ground component of the SBIRS system that consolidates satellite detection data, generates Quick Alert and Boost Phase Reports, and forwards them to the BMC3. From these reports, the BMC3 generates Sensor Task Plans that provide cues to the ground based radars for acquisition of the target complex. The SBIRS system is being developed as an Air Force program.

4. Ground-Based Sensors

The NMD C1 architecture includes six ground-based radars: five Upgraded Early Warning Radars and a single X-Band Radar that is currently under development.

The UEWRs are upgraded versions of the Air Force's existing UHF phased-array ITW/AA surveillance radars. They can operate autonomously or search for threat objects in response to cueing from the BMC3. The UEWRs are expected to track all threat objects and attempt to classify them as "threatening" or "non-threatening." Such information is provided to the BMC3 for supporting the generation of Weapon Task

Plans[11] and In Flight Target Updates. If the intercept occurs within their coverage volume, the UEWRs will collect intercept data to support a kill assessment made by the BMC3.

The X-band, phased-array radar based in Shemya, Alaska, provides radar coverage for a subset of threats aimed at Alaska, Hawaii, and the Western United States. In most cases, it cannot participate in engagements that threaten the Eastern Seaboard. Responding to cueing from the BMC3, it acquires threat objects, tracks them with great accuracy, and attempts to discriminate the RV from decoys and associated objects. Such information is provided to the BMC3 for supporting the engagement. The XBR will also collect kill assessment data, if the intercept occurs within its coverage volume.

B. NMD ACQUISITION STRATEGY – PHASED DEPLOYMENT

In April 1996, the DoD comprehensive review of its theater and national ballistic missile defense programs shifted NMD from a Technology Readiness Program (1993-1996) to a Major Defense Acquisition Program (Acquisition Category 1D), known as the NMD "3+3" Deployment Readiness Program. This program called for three years of intensive development work, followed by a deployment decision in FY00 that could result in an IOC three years later (FY03).

In January 1999, the Secretary of Defense redirected and modified the NMD program to implement a phased deployment approach, based upon technical progress, leading to an operational system as early as the end of FY05. The first decision point, the DRR, is to decide on the following issues: a recommendation to the Secretary of Defense whether to commit to deployment of the C1 system, selection of sites for all the elements, award of site-construction contracts, long haul communications, and approval of long lead radar hardware.

The January 1999 restructuring of the NMD program also added two other decision points (phased approach).

- An FY01 DAB will consider the building and/or upgrading of required ground-based radar systems – XBR and UEWR – and the integration of command and control software into the Cheyenne Mountain Operations Center.

---

11 A Weapon Task Plan consists of pre-launch instructions that are used by the weapon system for generating a flyout solution that places the EKV on an intercept path with the target RV. Such a plan is required before an interceptor is committed/launched to engage the threat.

- An FY03 DAB will determine if the weapon system is ready for C1 production and deployment.

In the spring of 1998, the Ballistic Missile Defense Organization awarded the Lead System Integrator (LSI) contract to Boeing North American. Boeing[12] serves as the prime contractor for NMD system development and is responsible for integrating the NMD elements. In addition, Boeing is responsible for demonstrating and verifying system capability through integrated ground testing, integrated flight testing, and modeling and simulation.

12 In this report, "Boeing" is synonymous to "Lead System Integrator."

IV. TEST ADEQUACY AND RESULTS

A. TEST PROGRAM

The NMD Test and Evaluation Program is being planned and executed by the NMD Lead System Integrator, Boeing, under the direction of the NMD Joint Program Office. The test program is derived from the current NMD Test and Evaluation Master Plan (TEMP) and aims to demonstrate, incrementally, progress toward C1 capability by fulfilling the following objectives:

- Demonstrate end-to-end integrated system performance, including the ability to prepare, launch, and fly-out a designated weapon; and kill a threat-representative target through body-on-body impact.
- Demonstrate end-to-end target detection, acquisition, tracking, correlation, and handover performance.
- Demonstrate real-time discrimination performance.
- Demonstrate NMD system kill assessment capability.
- Demonstrate the ability of the NMD battle management software to develop and coordinate battle engagement plans; prepare, launch, and fly out a designated weapon, and kill a threat representative target.
- Demonstrate integration, interface compatibility, and performance of system and sub-system hardware and software.
- Demonstrate human-in-control operations of the NMD system.
- Demonstrate system lethality.

In the first three years of the NMD program – the Initial Development Phase – test events consisted of Integrated Ground Tests (IGTs) 3, 4, and 5; Integrated Flight Tests (IFTs) 1A, 2, 3, 4, and 5; Modeling and Simulation activities; Risk Reduction Flights (RRFs); and User Exercises. This phase culminates with the DRR. Near-term test and evaluation focuses on the ability to provide accurate test information and data in support of the DRR. Test and evaluation activities are also essential for the development and maturation of system elements.

The NMD program activities following the DRR will focus on completing the development and deployment of the NMD C1 system. The test and evaluation activities during this period consist of Integrated Ground Tests, Integrated Flight Tests, Modeling and Simulation, Risk Reduction Flights, and User Exercises – as for the initial development phase – and are intended to support developmental activities and the FY01 and FY03 DAB decisions. The FY01 DAB will decide whether to proceed with the UEWR Upgrade, XBR build, and BMC3 integration into the Cheyenne Mountain Operations Center, and the FY03 DAB decision will decide if the weapon system is ready for production and deployment.

B. LIMITATIONS ON INTEGRATED FLIGHT TESTS

The flight test program has demonstrated basic functionality and interoperability of the NMD system. The most notable achievements have been the hit-to-kill intercept of IFT-3 and significant "in-line" participation in IFT-4 and IFT-5 by system elements. However, the configuration of the NMD system during both IFT-4 and IFT-5 remains a limited functional representation of the objective system, as discussed below.

Early integrated flight tests, like IFT-4 and IFT-5, make use of surrogate and prototype elements, because the NMD program is still in its developmental phase. As such, element maturity in near-term flight testing is limited:

- An interim build of the BMC3 – Capability Increment 3A – will be utilized in all integrated flight tests through IFT-6. It is a build with about 60% of the planned functionality but has the basic engagement functions necessary to execute a mission. The next build, Build Increment 1, may not add any new functionality but will begin the re-hosting of the software onto a Defense Information Infrastructure / Common Operating Environment and Joint Technical Architecture compliant architecture. IFT-7, scheduled in FY01, will be the first time Build Increment 1 is used in an integrated flight test.
- Defense Support Program (DSP) satellites, which provide launch warning to the BMC3 in the form of Quick Alert messages, act as the Space Based Infrared System element. DSP satellites are not able (and were not designed) to perform surveillance and boost track functions at the levels necessary to meet NMD ORD system effectiveness requirements, and therefore, will be replaced by SBIRS satellites. DSP messages are not currently in NMD tactical format and, during integrated flight testing, require message

translation by range assets at the Joint National Test Facility[13] before being forwarded to the BMC3.

- The Payload Launch Vehicle, a two-stage booster system consisting of modified Minuteman II motors and supporting subsystems, has been the surrogate for the interceptor booster in all integrated flight tests to date. The tactical booster[14] was scheduled to be flown in IFT-7 (*cf.* Figure II-1), but schedule slips in Boost Vehicle testing have delayed the first flight of the tactical booster to IFT-8.
- The Ground Based Radar Prototype, located at Kwajalein Missile Range (KMR), supports integrated flight tests as the prototype element for the X-Band Radar. GBR-P participation in integrated flight tests is limited, because as discussed below, its siting at KMR precludes it from adequately supporting weapon task planning by the BMC3. As a result, Global Positioning System (GPS) instrumentation and/or a C-band transponder on the target reentry vehicle are the sources of information for weapon task planning by the BMC3.

In part, the operational realism of integrated flight testing has been limited by having located the GBR-P at KMR. As illustrated in Figure IV-1, the GBR-P is not sufficiently forward in the test geometry, as it would be in many operational scenarios,[15] requiring that other sensors provide data to the BMC3 for weapon task planning. In the integrated flight tests conducted to date and for the foreseeable future, these "other sensors" are either GPS data sent from the RV and/or the FPQ-14 radar receiving data from a C-band transponder on the target RV. The FPQ-14 radar located on Oahu, Hawaii, picks up the C-Band signal radiating from the target RV and provides the BMC3 with target track information as though it were from a UEWR. Similarly, as in IFT-3 and IFT-4, the GPS can provide the BMC3 with target track information as though it were from an X-Band Radar. In tests to date, the BMC3 was required by the concept of operations to generate a Weapon Task Plan only after the threat object – the RV – had been resolved by ground based radars.[16] Although the GBR-P acting as the XBR

---

13 The Joint National Test Facility is located at Shriever Air Force Base near Colorado Springs, Colorado.

14 The tactical booster is a Commercial-off-the-Shelf (COTS), three-stage, ICBM-class missile that has a burnout velocity nearly 2.5 times that of the PLV. Launched from central Alaska, the tactical booster must be powerful enough to engage threats, in a timely manner, targeted at the East Coast.

15 Missiles launched from eastern Asia would generally come into the X-Band Radar's field of view much earlier than in test scenarios. Missiles coming over the North Pole or from the Middle East would generally have to rely on other sensors for generating the Weapon Task Plan.

16 The NMD system is required to engage the threat under one of three "categories" of operation: (A) resolved and discriminated RV; (B) cluster track of threat complex; or, (C) space-based sensor data of boosting missile.

surrogate can acquire the target *cluster* soon after radar horizon break, the GBR-P alone is not capable of supporting the Weapon Task Plan generation since the target RV cannot be discriminated early enough.

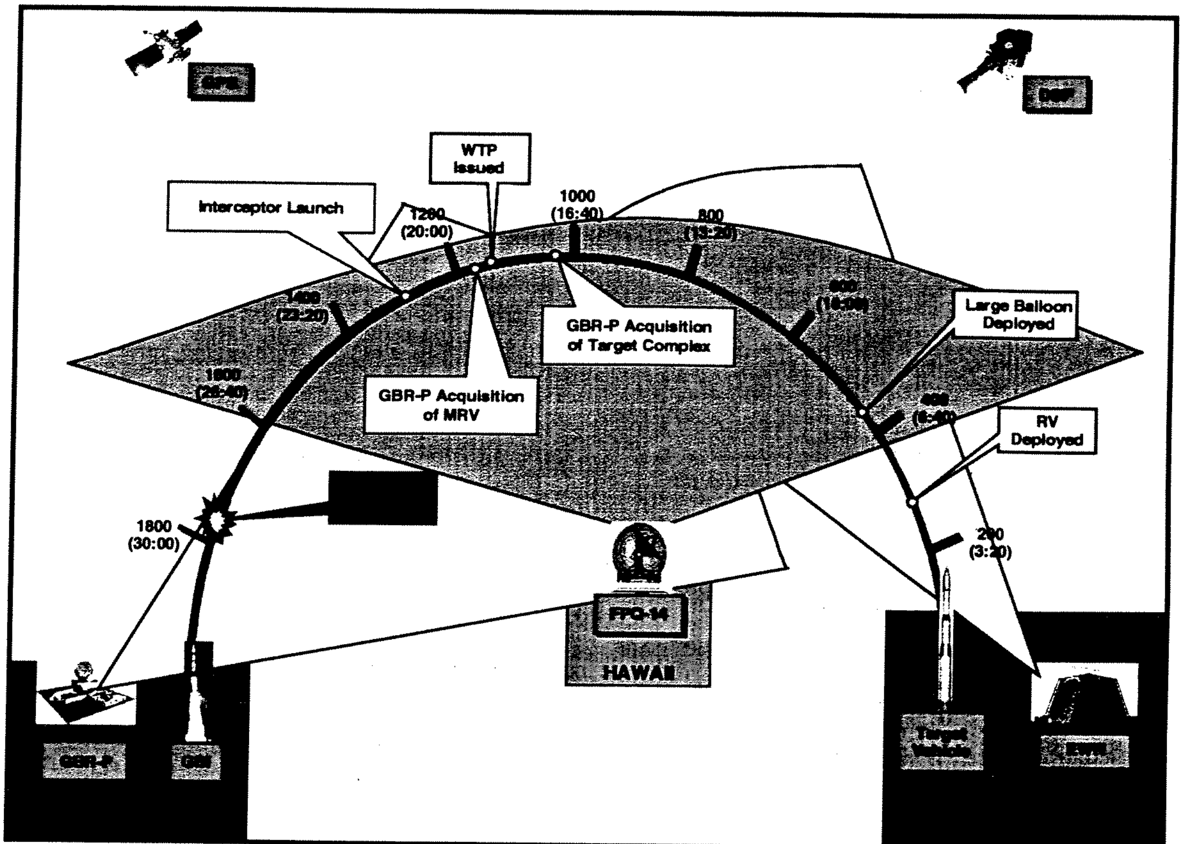

Figure IV-1. Integrated Flight Test Geometry

Another critical function performed by the BMC3 is the generation and uplink of In-Flight Target Updates (IFTUs) – target data sent to the EKV while in flight – to correct for any targeting errors. In the "on-line" portion of IFT-3, the GBR-P acting as the XBR surrogate was not required nor planned to be the sole provider of track data to the BMC3 for IFTU generation. Rather, GBR-P track data was augmented by FPQ-14 data for IFTU generation. GBR-P participation in IFTU generation – especially of IFTUs sent late in the engagement timeline – has increased in recent flight tests. In particular, the BMC3 generated all three IFTUs exclusively from GBR-P data in IFT-5.

Characteristic of ballistic missile defense flight tests, limitations associated with developmental testing impact the operational realism of integrated flight tests. Safety concerns about intercept debris and range constraints impose limitations on engagement scenarios. While a successful intercept during any future flight test will be a significant achievement in the development of the NMD system, it should be seen in context of the caveats enumerated above as well as the following limitations:

- **Engagement Conditions.** Test target launches from Vandenberg Air Force Base (VAFB) and interceptor launches from KMR place significant limitations on achieving realistic engagement conditions. A target missile cannot be launched from a "threat country" toward the United States. Test targets are outbound from the United States rather than inbound relative to early warning radars. Consequently, during flight tests, early warning radars track the target complex during phases of its flight different from what is expected during a true engagement. The target missile launched near the early warning radar presents an easy target for detection and is tracked during its boost phase. Other limitations on engagement conditions include the fact that interceptor flyout range and time of flight are short,[17] intercept altitudes are low (for debris containment), and closing velocities during the endgame are not stressing. These limitations would be mitigated somewhat with the addition of a new test geometry to the flight test program: for example, target launches from Kauai or Wake Island and interceptor launches from Kodiak Launch Complex in Alaska, or target launches from Kodiak and interceptor launches from KMR.
- **Target Suite Reduction.** The target suites flown in IFTs 3, 4, and 5 each contained only two objects – a Medium Reentry Vehicle (MRV) and a Large Balloon – a significant reduction in complexity from the original plan. Target requirements listed in the JPO-signed 1997 TEMP called for nine to ten objects in flight tests IFT-1 through IFT-5, suites that contained both unsophisticated and sophisticated decoys In 1998, target requirements were pared down to three balloons (one large and two small balloons) and the MRV. Then, in July 1999, less than three months before IFT-3, the target suite was further reduced to two objects, as indicated above. In all cases, the deployment bus is in the field of view of the EKV seeker and also has to be discriminated.
- **Target Suite Complexity.** The NMD test program is designed to test within the C1 threat space, which means that target suites in flight tests will have at most unsophisticated countermeasures, even though the threat from accidental or unauthorized launches could employ sophisticated countermeasures. Currently, the most stressing intercept flight tests will fly target suites consisting of a mock warhead and a collection of simple balloon decoys. The target suites flown in IFT-3, IFT-4, and IFT-5 were each limited to an MRV

---

17 An issue related to the short interceptor flyout is that the COTS booster is nearly too powerful for flight testing with short GBI flyout ranges. The LSI and JPO are considering options – e.g., not firing the third stage or initiating extreme general energy management – to resolve this issue.

and a Large Balloon. Signature simulations show that since the large balloon and deployment bus have IR signatures very dissimilar to the MRV, the EKV can easily discriminate the MRV from these objects.

- **Multiple Simultaneous Engagements (MSE).** NMD system performance against multiple targets is not currently planned for demonstration in the flight test program, although multiple engagements are expected to be the norm in NMD system operation. The Joint Program Office has plans for constructing a second interceptor silo at Kwajalein Missile Range as well as a second missile silo at VAFB, therefore, some of the additional infrastructure cost for performing such testing is already in the NMD budget. From a technical viewpoint, Multiple Simultaneous Engagement testing is considered essential for the following reasons:
  - There may be unanticipated synergistic effects between simultaneously deployed EKVs; many questions or issues simply cannot be resolved from the testing of 1-on-1 engagements. Debris, BMC3 workload, discrimination, etc., all make extrapolating from 1-on-1 to more likely scenarios uncertain.
  - Effectiveness requirements pertaining to M-on-N engagements will be carried out through modeling and simulation. In order to have traceability to the real world, these simulations need "anchoring" and validation from M-on-N flight-testing.

Operational engagements for the NMD C1 System are expected to cover a much larger engagement space than what can be achieved during integrated flight tests. Figures IV-2, IV-3, and IV-4 illustrate the differences. Figure IV-2 shows that targets launched from VAFB in California toward KMR in the Western Pacific occupy one point of the target-apogee vs. target-range parameter space. Figure IV-3 underscores the fact that interceptor flyout in the VAFB-KMR engagement is on the very low end of the engagement space – a flyout range of roughly 700 kilometers – and at a fixed intercept altitude of 230 kilometers. And, Figure IV-4 compares the flight envelope – closing velocity vs. interceptor ground range – of the test program to that of the C1 engagement space. The engagement space of the test program occupies nearly a single point.

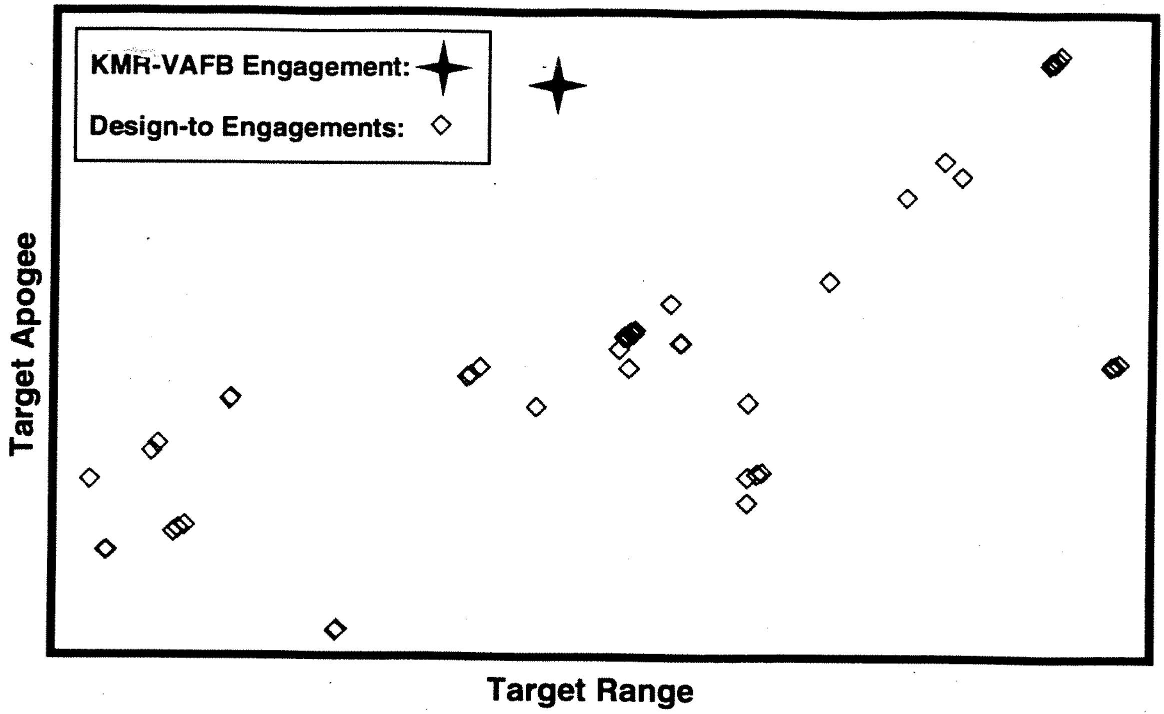

Figure IV-2. Target Apogee vs. Target Range Parameter Space

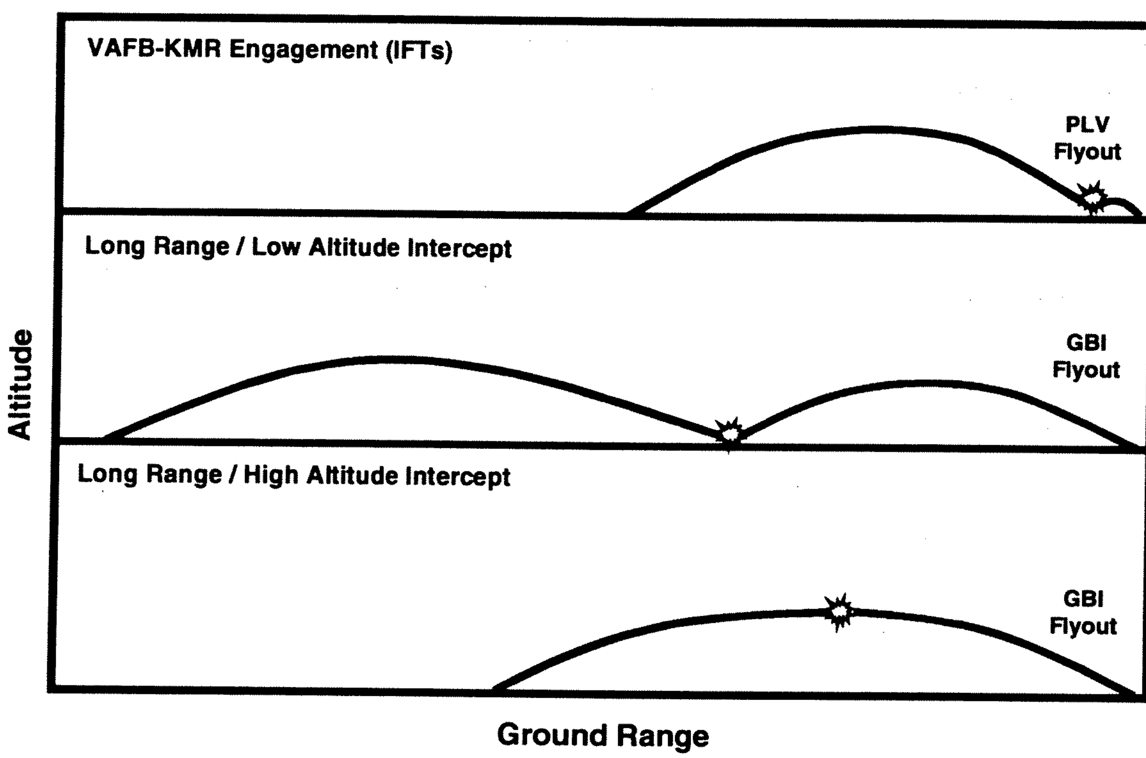

Figure IV-3. Interceptor Flyout Comparisons

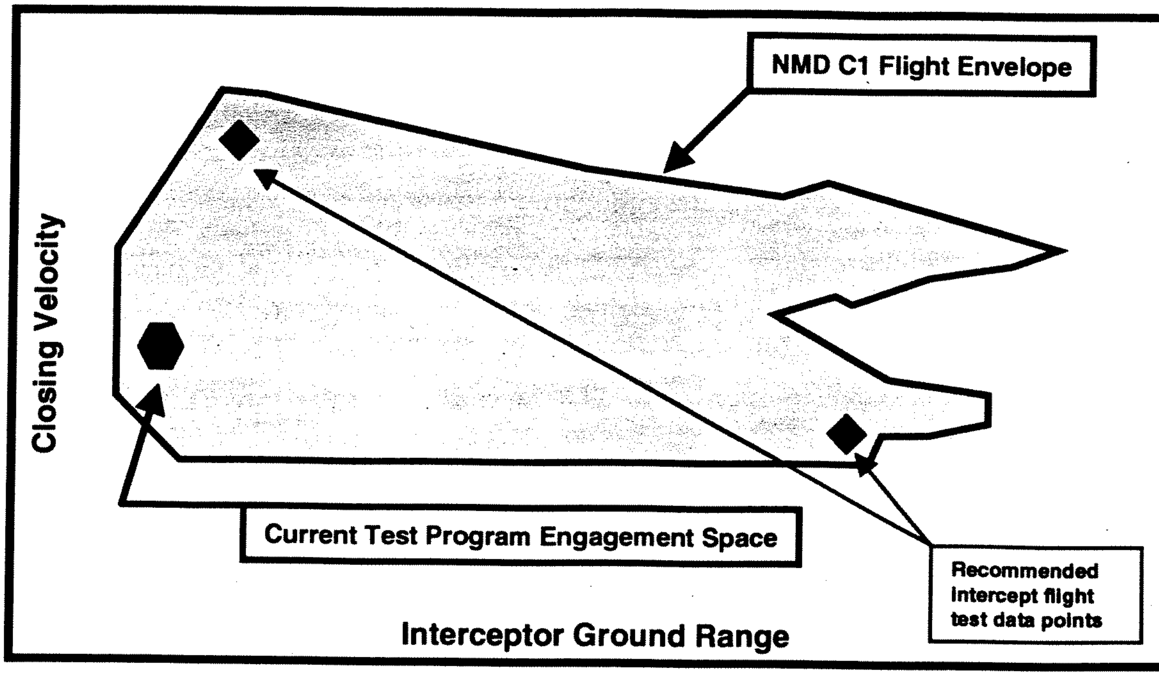

Figure IV-4. Closing Velocity vs. Interceptor Ground Range Parameter Space

Integrated ground testing using simulated environments and full threat scenarios will be used to evaluate the performance and effectiveness of the NMD C1 system throughout the engagement envelope. These ground activities, along with modeling and simulation, are planned to mitigate flight test limitations described above. Unless additional points in the flight envelope of Figure IV-4 are flown in integrated flight tests, the scope and validity of system performance estimated in ground testing would remain limited.

C. FLIGHT TEST RESULTS

1. Integrated Flight Test 1A – Boeing EKV Flyby

Integrated Flight Test 1A (IFT-1A), conducted on 24 June 1997, was the first flight test of the NMD Test Program. A test was attempted in January 1997 (IFT-1) but was aborted because the surrogate for the ground based interceptor booster failed to launch. The primary objective of IFT-1A and the subsequent test, IFT-2, was to provide a basis for down-selecting candidate EKVs built by competing contractors, Boeing and Raytheon.

IFT-1A assessed the performance of the Boeing EKV sensor, collected phenomenological data used for post-test analysis of the onboard discrimination algorithms, and collected functional data on the dynamic flight-test environment and its effects on the EKV. Range assets and surrogate hardware – GPS and the FPQ-14 radar tracking a C-band transponder – were used to guide and deliver the EKV to a point in space where it began executing sensor functions; the BMC3 element played no role in the execution of IFT-1A. Since the EKV did not have propulsion capabilities, it was incapable of intercept but came to within 5200 ft of the target reentry vehicle.

The principal component of the Boeing EKV design is a multiple-waveband IR sensor that allows the EKV to acquire, track, and collect data on objects of the representative threat target suite. The sensor payload consists of a focal plane array of highly sensitive silicon-based sensors and a cryogenic cooling assembly at the end of an optical telescope.

The EKV sensor payload was launched from Meck Island in the Kwajalein Atoll and set on a trajectory that permitted it to view a pre-planned target scene. The target suite was launched from VAFB using a specially configured Minuteman II booster and consisted of nine objects: one medium reentry vehicle, two medium rigid light replicas, one small canisterized light replica, two canisterized small balloons, two medium balloons, and a large balloon. Viewing objects of the target suite, the EKV seeker successfully gathered signature and phenomenology data which, in turn, were used to verify predictions made by corresponding models and simulations. One of the medium balloons did not fully inflate.

- Nine of ten objects of the target suite (including the deployment bus) were detected, acquired, and tracked. For some unknown reason, one of the canisterized small balloons was not observed. As stated in the GBI 60-Day Report for IFT-1A, "No object detected on the focal plane could be correlated with the white canisterized small balloon; therefore, no seeker measurements for this object are available."
- Space (exoatmospheric) operation of the silicon seeker was verified.
- The EKV seeker collected IR signature data that were downlinked to ground receiving stations. Predictions from target signature models match seeker measurements acquired in flight for both IR bands.
- Using IR signature data collected by the EKV, post-test execution of discrimination algorithms were able to discriminate successfully the medium reentry vehicle as the threat object of the target suite. The successful discrimination of the medium reentry vehicle should not viewed as a

verification of the discrimination algorithms in an operational engagement, but rather, as a successful experiment.

2. Integrated Flight Test 2 – Raytheon EKV Flyby

Integrated Flight Test 2 (IFT-2) conducted on 16 January 1998 was the second flight test of the NMD Test Program. The objectives of IFT-2 were the same as that for IFT-1A, namely, to assess the performance of the EKV sensor built by the second EKV contractor, Raytheon Missile System Company. The same target suite of nine objects was flown.

EKV seeker data was downlinked and used for evaluating sensor performance and for performing post-test discrimination and signature analyses of the target suite. Range assets and surrogate hardware – GPS and the FPQ-14 radar tracking a C-band transponder – guided the EKV to a point in space where it began executing sensor functions; the BMC3 element played no role in the execution of IFT-2. As in IFT-1A, the Raytheon EKV did not attempt to intercept the medium reentry vehicle since it had no propulsion capabilities.

The principal component of the Raytheon EKV design is a multiple-waveband, Visible/IR sensor payload that allows the EKV to acquire, track, and collect data on objects of the representative threat target suite. The sensor payload consists of a HgCdTe focal plane array and a cryogenic cooling assembly at the end of an optical telescope. As in the launch of the Boeing EKV, the Raytheon EKV sensor payload was launched from Meck Island at KMR and set on a trajectory that permitted it to view a similar target scene of ten objects (nine objects of the target suite plus the deployment bus). And, as in IFT-1A, one of the medium balloons did not fully inflate.

IFT-2 was successful in collecting target object data, and post-test analyses demonstrated that the MRV could be discriminated from the other objects of the target suite. Because the discrimination algorithms were not executed in real time and relied on simulations that were anchored by IFT-2 test data, the successful discrimination of the medium reentry vehicle should not be viewed as a verification of the discrimination algorithms in an operational engagement, but rather, as a successful experiment.

At the recommendation of the Lead System Integrator (Boeing North American), the NMD Joint Program Office opted to down-select to a single EKV design prior to IFT-

3, which afforded more intercept test opportunities before the DRR. The Joint Program Office selected Raytheon as the EKV contractor over Boeing.[18]

3. Integrated Flight Test 3 – Intercept Achieved

The first NMD *intercept* attempt of a target reentry vehicle by the Raytheon-built EKV was successful, albeit with significant limitations to operational realism, on 2 October 1999. IFT-3 began with the launch of a Minuteman-based booster from VAFB and the subsequent deployment of its target payload – MRV and Large Balloon – for reentry near KMR. An interceptor was launched from Meck Island to engage the MRV, and EKV intercept of the MRV occurred at an altitude of 230 km, 1782 seconds after target liftoff. IFT-3 was planned and jointly executed by the NMD Joint Program Office and Boeing, the LSI. Future flight tests will be planned and executed by Boeing.

IFT-3 was an element test of the Raytheon-built EKV, not an Integrated System Test. IFT-3 was comprised of two concurrent test activities: an "in-line" test that focused on the performance of the EKV, and a simultaneous "on-line" or shadow test that focused on assessing NMD functionality as an integrated system using prototype elements that approximate the objective system. The principal objective of the on-line test was to demonstrate integration and operation of system elements as a risk reduction effort for future flight tests, IFT-4 and IFT-5.

IFT-3 In-Line Test (EKV Flight Test)

The in-line or flight test part of IFT-3 was a test of the Raytheon-built EKV. GPS track information of the target RV was used to guide and deliver the EKV to a point in space where it began executing mission-critical functions: midcourse guidance, target-complex acquisition, real-time discrimination, target selection, active homing, and intercept. Although the EKV successfully intercepted the MRV, acquisition of the target complex by the EKV was accomplished in an off-nominal manner because of a malfunctioning Inertial Measurement Unit (IMU) onboard the EKV. The IMU problem was caused by a vendor calibration procedure error, which was corrected for IFT-4.

Because of the problem with IMU operation, the EKV was forced to utilize its "step-stare" capability that comes on-line only during off-nominal situations.

---

[18] Originally, the EKV down-selection was to occur after IFT-3 and IFT-4, intercept attempts of a target RV by the Boeing and Raytheon EKVs, respectively.

- The IMU was unable to measure angular position (pointing) of the EKV with sufficient accuracy to allow for nominal target acquisition. Large angular slew rates of the EKV, performed during star shots to refine angular navigation, were directly responsible for the malfunction of the IMU. The anomalous behavior of this IMU should not be seen in future flight tests, because a new tactical IMU – built by Fibersense – will be used in the C1 EKV design and flown in integrated flight tests beginning with IFT-6 in January 2001.
- When the EKV "opened its eyes," no object of the target complex was in its field of view. The EKV executed the "step stare" procedure to extend its field of view and, subsequently, acquired the Large Balloon, deployment bus, and MRV. Had the Large Balloon not been deployed with the target suite, the EKV probably would have acquired the deployment bus and, subsequently, acquired and intercepted the MRV.
- Discrimination and target selection of the MRV from the Large Balloon and deployment bus were successfully accomplished. The guidance, navigation, and control functions were performed without incident and resulted in the intercept of the MRV.

IFT-3 On-Line Test (Shadow Test)

The on-line portion of IFT-3 ran in parallel with the in-line test to assess the performance of NMD functionality as an integrated system using prototype and surrogate elements. Elements operating on-line did not affect the operation of the in-line test but did demonstrate NMD functionality in a configuration more representative of the integrated system to be deployed. The most notable results of the IFT-3 on-line test pertained to BMC3 and GBR-P performance.

The BMC3 successfully demonstrated integrated system performance through the coordination of system elements operating in shadow mode. It performed engagement planning that ultimately led to a successful (simulated) mission. GBR-P performance was generally poor and unsuitable for anchoring associated radar simulations. GBR-P track quality was adversely affected by a software error in the antenna mount motion equation. A software fix was implemented and later verified in the target of opportunity flight, RRF-7, which was conducted in November 1999, IFT-4, and IFT-5.

4. Integrated Flight Test 4 – Intercept Not Achieved

Integrated Flight Test 4, which was conducted on 18 January 2000, was the first *end-to-end* NMD flight test attempting a hit-to-kill intercept of a target reentry vehicle.

Whereas IFT-3 was an element test of the Raytheon-built EKV, IFT-4, using surrogate and prototype elements, strived to demonstrate NMD system integration in a configuration more representative of the system to be deployed. In particular, both the BMC3 and the GBR-P participated in the flight test "in-line." The FPQ-14 radar located in Oahu, Hawaii, was to have used the C-Band transponder data from the MRV to provide the BMC3 with target track information as though it were from a UEWR. The FPQ-14 data, however, was (erroneously) judged in real time to be of poor quality. Instead, GPS track data of the MRV was used in IFT-4 after being translated into XBR format. The geometry of the test scenario of IFT-4 was identical to that of IFT-3.

The EKV failed to intercept the MRV, a failure directly traceable to the cryogenic cooling system of the EKV. The primary cooling line that delivers krypton to the IR focal plane arrays was restricted with either frozen moisture or contamination, and the IR sensors were prevented from cooling down to their operating temperatures. Consequently, the IR sensors did not acquire or track target objects for terminal homing and intercept.

IFT-4 demonstrated the successful operation and integration of NMD elements. Data analysis of IFT-4 has been completed, and the following assessment of test results can be made:

- **Battle Management, Command, Control, and Communications**. The non-tactical flight test version of the BMC3 operated in a fully functional, dual node configuration (Commander-in-Chief and Site). In particular, the BMC3 demonstrated end-to-end tracking of the target complex and successfully generated Weapon Task Plans, Sensor Task Plans, one of three In-Flight Target Updates, and a Target Object Map.
- **Defense Support Program**. DSP satellites successfully acquired the boosting Minuteman II target vehicle and sent Launch Alert and Boost Event Reports to the BMC3.
- **Early Warning Radar Test Article**. Post-mission analysis indicates that the EWR provided the BMC3 with sufficiently good track data of the target cluster for successful GBR-P cueing. It must be noted, however, that the EWR test article is located up-range and has the advantage of tracking targets at close range as opposed to longer ranges expected in typical NMD engagements. At close range, the radar return signal is large, which enables the radar to generate higher quality tracks of deployed objects.
- **Ground Based Radar-Prototype**. The GBR-P participated in IFT-4 as a surrogate X-Band Radar element. Its participation in IFT-4 as an *integrated* element of the system was limited, since its track data and discrimination

information was not utilized by the BMC3 for the generation of the Weapon Task Plan. The GBR-P was successful in many respects: it acquired the target complex, tracked and resolved all objects of the target complex, and correctly discriminated all tracked objects as either tank-like, debris, or RV. In addition, the GBR-P supplied track information used by the BMC3 for the generation of one IFTU.

5. Integrated Flight Test 5 – Intercept Not Achieved

Integrated Flight Test 5 was conducted on 8 July 2000. It was to be an end-to-end NMD intercept flight test nearly identical to IFT-4 and aimed to demonstrate NMD system integration with surrogate and prototype elements in a configuration representative of the system to be deployed. The most prominent new feature of the test was the participation of the In Flight Interceptor Communications System as the communication link between the BMC3 and EKV. As in all previous intercept tests, a Minuteman-based target system was launched from VAFB, and its target payload consisting of an MRV was deployed for reentry near KMR. The target payload also included a Large Balloon, but it was never deployed because of some unknown failure of the deployment mechanism. Then, at 1294 seconds after target liftoff, an interceptor was launched from Meck Island to engage the MRV. The planned intercept, which did not occur, was to have been at an altitude of 230 km, 1782 seconds after target liftoff, identical to the planned intercepts on IFT-3 and IFT-4.

The failure to intercept the MRV is the direct result of the EKV not separating from the upper stage assembly of the Payload Launch Vehicle, the surrogate for the interceptor booster. Preliminary failure analysis of the telemetry data indicates that the EKV did not receive a second-stage burnout message, a prerequisite for initiating the separation sequence. The cause of this failure has not yet been determined but appears to be isolated to the Payload Launch Vehicle. A notable consequence of the failure is that all EKV events subsequent to separation, e.g., sensor operation and divert and attitude activities, did not occur. Therefore, none of the EKV primary objectives were met.

The FPQ-14 radar located at the Kaena Point Satellite Tracking Station in Oahu, Hawaii, which tracked the C-Band transponder on the MRV, played an important role in IFT-5. Unlike IFT-4 in which GPS track data was the source for Weapon Task Plan generation, the BMC3 generated the Weapon Task Plan using FPQ-14 transponder data. GPS was still used, however. The FPQ-14 data, prior to being used to generate the Weapon Task Plan, was checked against the GPS track for accuracy; GPS data could have been used in the event that FPQ-14 data was of poor quality.[19] The Weapon Task Plan directed the launch of the interceptor at 1294 seconds TALO.

The GBR-P, the prototype X-Band Radar, successfully participated in IFT-5 as an integrated element of the system. It received target cluster cues from the BMC3, tracked all objects of interest, and correctly performed real-time discrimination on all target objects. The GBR-P tracking and discrimination timeline of IFT-5 closely matched the timeline predicted by pre-mission simulations, except that MRV acquisition occurred earlier than predicted. GBR-P participation in integrated flight tests is increasing. In IFT-5, all In Flight Target Updates (IFTUs) including the backup IFTU were generated solely from GBR-P track data. However, GBR-P track data was prevented from entering the BMC3 element until after the Weapon Task Plan had been sent to the Weapon System and, therefore, did not contribute to Weapon Task Plan generation.[20]

IFT-5 demonstrated integrated system performance through the operation of the non-tactical, flight-test version of the BMC3. The BMC3 provided end-to-end tracking of the target complex utilizing multiple sensor sources and demonstrated all operations of engagement planning and real-time communications. It successfully generated the Weapon Task Plan, Sensor Task Plans, Communication Task Plans, and IFTUs. Failure of EKV operation precluded the successful in-line operation of the IFICS – closure of the BMC3-EKV communication link – and, thus, associated objectives were not fully achieved, e.g., the receipt of In Flight Status Reports from the EKV were not evaluated. System integration of early warning elements with the BMC3 was achieved: DSP satellites successfully acquired the boosting Minuteman II target vehicle and sent Quick Alert and Boost Event Reports to the BMC3. The EWR also acquired and tracked the target complex, including spent fuel tanks, early in the mission timeline.

D. INTEGRATED GROUND TESTS

Boeing is performing ground testing to mitigate the risks associated with the limited flight test program. Ground testing can exercise the system through variation of threat characteristics such as launch point, aimpoint, trajectory, apogee, number of RVs, target type, and environmental effects. This ground testing is done in month-long phases

---

19 In IFT-4, the FPQ-14 transponder track data was judged to be of unsatisfactory quality and, therefore, only GPS data was used to generate the Weapon Task Plan.

20 The GBR-P is unlikely to resolve and discriminate the RV from other objects in the target cluster early enough to generate a weapon task plan. The test plan for all intercept tests to date call for launching the interceptor only after the RV has been resolved and identified.

called Integrated Ground Tests. IGT-4 and IGT-5 occurred in 1999; IGT-6 will not occur until after the DRR.

These ground tests use the Integrated System Test Capability (ISTC) at the U.S. Army Space and Missile Defense Command's Advanced Research Center in Huntsville, Alabama. ISTC provides test execution and control, threat and environment data, and test drivers for some NMD elements. Each NMD element is represented at a standalone computer station called a node. Each node incorporates system element mission and communications processors, which run prototype element software. ISTC supplies the nodes with simulated inputs – threats and associated environments, natural and man-made – which are nominally consistent for each NMD element in the scenario.[21]

IGTs use a combination of models, software-in-the-loop, and hardware-in-the-loop to test the NMD engagement space and threat in an operational environment. They are supposed to validate the functionality and functional interfaces between the elements, subject the system to stressing environments and tactical scenarios, and evaluate target-intercept boundary conditions. IGTs can help to identify "unknowns" in an interactive system context and verify interoperability of NMD system elements.

There was very little operational hardware or software used in IGT-4 or IGT-5. The BMC3 was a prototype, flight-test version of the operational BMC3; it included some real communications hardware (T1 links). It is *possible* that some of the software in the UEWR representation could eventually be used in the operational UEWR. Also, some of the EKV digital signal processing software and data processing software might be used in the operational EKV.

The element hardware components are represented digitally in the Processor Test Environment. It duplicates the real-time tactical interfaces in order to inject the perceived data into the test article. For example, the Processor Test Environment for the GBR-P element contains simulation software that represents the transmitter, receiver, antenna, signal processor, measurement generation, beam volume, detection response, and radar status.

IGT-4 and IGT-5 had a number of limitations. For example, the threat apogees were unrealistically high in IGT-4, which provided optimistic assessments of timelines and radar detections. Because the simulation had limited processing capability, Boeing (LSI) eliminated most of the threat objects in many of the scenarios, which was

21 One exception is the gravity model, which is different for the EKV and the other elements.

unrealistic for testing discrimination, radar resource management, and BMC3 processing capabilities. In addition, all of the element representations suffered from limitations that produced significantly different performance than is expected from the NMD C1 system. These limitations included, but were not limited to:

- Only five high-fidelity representations of the EKV were available. There were 15 low fidelity models, but the two representations could not be used together. Thus, a full-up scenario involving multiple RV attacks could not be represented.
- UEWR representations did not include pulse integration, leading to lower than expected signal-to-noise ratios and objects not being tracked.
- UEWR tracking accuracies often failed to meet specifications.
- The XBR was represented by a modified GBR-P model that differed in power-aperture product, field-of-view, sensitivity, slew rate, etc. Work-arounds such as increases to target cross sections were implemented to mitigate some, but not all, of these limitations.

The primary goal of IGT-4 and IGT-5 was to demonstrate the integration of BMC3 with the UEWR and XBR. Boeing successfully demonstrated integration between these three NMD elements in the two IGTs. The secondary goal of the IGTs was to assess the C1 architecture and performance against a limited set of C1 scenarios. This goal was less successful, in part because of the immaturity of the element representations in IGT-4 and IGT-5. The exact amount attributable to element model immaturity is currently undefined and will remain so until truly element-representative models are installed in ISTC.

Boeing demonstrated integration between the BMC3 and radars by generating and recording messages between the elements. They confirmed that the planned messages had been exchanged between the BMC3 and the GBR-P and UEWR, and measured the time delays between the messages.

The radar performance in IGT-4 and IGT-5 was generally poor. In IGT-4 the XBR had reasonable position track performance but the velocity track performance was much worse than specifications. The XBR improved in IGT-5 and usually met the track accuracy performance. The UEWR failed to detect a significant number of RVs in IGT-4 and IGT-5. Once an RV was acquired, the performance of the UEWR representation at a given time was generally much better than specifications in both position and velocity tracking. However, the UEWR rarely succeeded in maintaining the specified track accuracies against RVs throughout an engagement. The probability of track maintenance was well below the NMD system specification requirements for both the XBR and UEWR. The XBR discrimination results were also well below the NMD system specification requirements.

The ISTC hardware and software used to date in the IGTs are immature and do not provide an adequate representation of the NMD C1 architecture. None of the major NMD elements – BMC3, XBR, UEWR, Weapon System, and DSP/SBIRS – is mature enough to provide a good assessment of the C1 system. The 1997 TEMP discussed the consequences if the representations were not mature before the DRR: "The validity and credibility of the surrogates and the representations must be fully characterized with respect to the NMD system and element requirements prior to making any decisions based on data drawn from tests using these systems. Without this information, the results of the tests will be inconclusive at best and misleading at worst." IGT-4 and IGT-5 did demonstrate the integration of the BMC3 with the UEWR and XBR (not with the weapon system, however), but these tests will provide only limited data to support an evaluation of the effectiveness of the proposed NMD C1 system at the DRR.

E. BATTLE PLANNING EXERCISE 99-5 AND BMC3 ASSESSMENT

Battle Planning Exercise 99-5 (BPEx 99-5) was conducted in the BMC3 Element Laboratory at the Joint National Test Facility on 28-30 September 1999. Conceived in 1998 by US Space Command (USSPACECOM/J35), BPEx events enable the User to examine and assess as-built BMC3 operational functionality for the purpose of influencing future development of the BMC3 element. The OTA Team was invited by USSPACECOM to co-lead BPEx 99-5 to benchmark BMC3 behavior in support of the Deployment Readiness Review.

The primary objective of BPEx events is to identify operational defects of the BMC3 element to be corrected in future builds. BPEx 99-5 was performed, in particular, to evaluate BMC3 element behavior in support of the OTA Team's early operational assessment of Key Performance Parameters #2 and #3 – human in control (HIC) and automated battle management – for the DRR. The evaluation of Key Performance Parameter #1, effectiveness of the NMD system to defend the US against ballistic missile attacks, was not an objective of BPEx 99-5. The test environment representing the NMD system consisted of the following components:

- Two representative nodes of the BMC3 element – CINC and Site – running Capability Increment 3A software.

- Trained military personnel – from USSPACECOM, NORAD, Army Space Command, and Air Force Space Command – were assigned specific roles as BMC3 operators during the exercises. These operators are known as "Smart Rounds" and underwent intensive training before the exercises were conducted.
- A "simulation cell" provided simulated external input from the national command authority (NCA) and ITW/AA to the CINC BMC3 node.
- The BMC3 Test Exerciser simulated the remaining elements of the NMD system: DSP/SBIRS, Upgraded Early Warning Radar, X-band radar, and the Weapon System.

Notable BMC3 Behavior

The following BMC3 behavior was observed during BPEx 99-5 execution:

- **Phantom Tracks (Track Splitting).** For scenarios in which the tracking of a threat object transitions from the XBR to a UEWR, the correlation algorithms of the BMC3 treat the UEWR returns as originating from a new, lethal object. In other words, the track of the "old" threat object splits into two tracks thereby creating a phantom track. Whenever there is sufficient battlespace for an engagement, the BMC3 battle manager would automatically allocate interceptors against this phantom object.
- **Battlespace (Time-to-Go) Bars.** The BMC3 software provides visual displays – blue horizontal bars – illustrating the time that remains for engaging a given threat object. These "time-to-go" graphics bars did not provide accurate situational awareness to the operator, because kinematic capability of the interceptor is the only constraint defining the time-to-go. The graphics bars do not reflect limitations from solar exclusion, IFICS loading, interceptor launch rates, intercept spacing, and nuclear weapons effects avoidance, for example.
- **Kill Assessment.** Whenever the BMC3 cannot make a kill assessment for a given engagement – because of a lack of radar coverage – an alarm is sounded and the target is treated as a "leaker." With the current radar architecture, kill assessments are frequently not available. Hence, the operator is led to believe that there are actual leakers and is dependent upon nuclear detonation reports from external sensors for situation awareness.

BMC3 Assessment

The BMC3 element is currently at an early stage of development and noted shortcomings are likely to be addressed before the planned initial operational capability in FY05. NMD operators had difficulty with resource management, engagement control, and situation awareness.

- **Resource management.** In the majority of scenarios, more interceptors than nominally required by the ORD were expended to defeat threat objects. For example, in a scenario with two RVs, 15 interceptors were launched. The reason for such behavior is two-fold:
  - Interceptors were launched against phantom tracks.
  - The BMC3 was very conservative during the exercises. Anything with a lethality-value greater than 0.02 (out of a maximum of 1.00) was engaged.
- **Engagement control.** When NMD operators believed that interceptors were allocated against phantom tracks, they tried a variety of techniques to override the automated battle manager to prevent the launch of interceptors.
  - Management-by-exception (MBE)[22] holds were placed on phantom tracks to prevent interceptors from being launched. Although such actions should have worked, they were unsuccessful in all cases. The system simply was not behaving according to operator actions. In any event, MBE was not intended by BMC3 developers to be used as a resource management tool.
  - The only successful technique used to prevent interceptors from being launched against phantom tracks was to allocate all remaining interceptors to reserve status.
- **Situation Awareness.** BPEx 99-5 indicated a lack of situation awareness on the part of NMD operators.
  - As mentioned above, battlespace graphics bars did not give NMD operators an accurate estimation of all times a threat object could be engaged. Engagements with short timelines were most problematic. There were scenarios for which the battle manager did not allocate interceptors – because the system did not have the battlespace to engage the threat – even though the associated graphics bars indicated positive battlespace. This was particularly frustrating to the operators who could not control the engagement to launch interceptors.
  - The possibility of phantom targets stemming from radar-to-radar handover tended to make NMD operators anxious. There was no tool that could definitively warn operators when a phantom track appeared, so the

---

[22] MBE is defined as the capability of the Human-in-Control to make inputs influencing the system engagement behavior on a track by track basis.

operators were forced to rely on their judgement in this regard. In the end, the operators tended to discount information derived from the UEWRs.

- The identification of threat objects as leakers for engagements without KAs forced operators to speculate on whether the engagement was successful.

The LSI is developing the BMC3 with maximum automation. Inherently, the BMC3 is designed to preclude direct launch control by the operator. Rather, positive control is exercised through Rules-of-Engagement development, battle-planning development, and management by exception. The BPEx, therefore, reflects the outcome of these efforts and can be frustrating to an operator attempting real time control.

F. MODELING AND SIMULATION

Restrictions on realistic operational flight testing force the T&E program to rely heavily on integrated ground testing and the execution of digital simulations for assessing the operational suitability and effectiveness of the NMD system concept. Integrated ground testing was of limited utility, as discussed in Section IV.D, in assessing the potential performance of the NMD system. Late delivery of LIDS – a high fidelity, system-level digital simulation of the NMD system – precluded its use for making a credible assessment of potential NMD system performance.

LIDS model development is taking much longer than expected. It was to be the principal digital simulation tool providing DRR support. Modeling and simulation in general and LIDS in particular were supposed to be employed to repeat hypothetical experiments in order to improve the statistical sample and to determine the values of key technical parameters unable to be measured by testing. Boeing released a beta version LIDS Build 4 at the end of April 2000. There was not enough time before the DRR to accredit LIDS and perform the required system analyses. As a result, the Service Operational Test Agencies do not have a simulation that they can use to assess the potential system effectiveness.

LIDS build 4 has serious limitations, so even if it had been released on time there would still be major issues in using LIDS to assess the potential performance of the NMD system. One problem is that LIDS users will not be able to generate their own scenarios. Boeing will provide users with canned scenarios, including fixed launch points, aim points, ICBMs, debris, and apogees. The Operational Test Agencies had been planning to run hundreds of digital simulation scenarios, varying such parameters as raid size, trajectories, atmospherics, debris, nuclear effects, threat launch and impact points, threat types, and Penetration Aids (PENAIDS). LIDS will not have the flexibility to support such studies.

LIDS will allow users some flexibility. They will be able to change the location and number of the various NMD elements. Users will also be able specify such parameters as the reliability of GBI boost phase completion, the probability of target acquisition by the EKV sensor, the probability of the EKV correctly identifying the RV, the probability of hitting the RV given correct discrimination, and the probability of killing the target given a hit. Such analyses will be useful but not sufficient to adequately assess the potential performance of the C1 system.

LIDS does not simulate any of the element prototypes or surrogates currently used in flight testing. Consequently, use of the IFTs to provide traditional model validation data will not be possible until the actual system elements finally work their way into the intercept flight test program. This limits the confidence that can be placed on LIDS predictions in the foreseeable future.

Boeing is using a number of low-fidelity simulations in their development of the NMD system. One is NMDSim, which estimates the interceptor launch windows for different scenarios. The NMDSim does not simulate discrimination functionality, does not generate weapon task plans, has no interceptor flyout representation, and does not perform kill assessment. It can be a useful tool for planning engagements in higher-fidelity models or simulations, but it is too limited to credibly assess the potential performance of the NMD system.

G. LETHALITY TESTING

NMD lethality testing and analysis activities before the DRR have focused on the development and accreditation of version 8.1 of the Parametric Endo-Exoatmospheric Lethality Simulation (PEELS). PEELS is the only lethality simulation to be accredited for endgame evaluation of NMD intercepts. In effect, it is the simulation used in both lethality and effectiveness analyses to assess whether an NMD hit on a threat target results in a target kill. To develop an NMD-capable version of PEELS, the database of empirical results that anchors the simulation for theater ballistic missiles had to be expanded to include lethality information for intercepts of NMD-type targets by the EKV in the velocity regime expected for NMD engagements. Because there is no capability to run ground tests at the upper end of NMD intercept velocities, a series of hydrocode analyses were used to generate the bulk of the "empirical data" for NMD EKV intercepts.

A total of 490 hydrocode simulations are planned, covering the quarter-scale Light Gas Gun test projectile, warhead and aeroshell damage, and different threat targets and intercept parameters. Of these, 218 have been completed to date, namely, 178 for the Attitude Control Reentry Vehicle target and 20 for Medium Lethality Reentry Vehicle target. The main purpose of the quarter scale Light Gas Gun series was to generate instrumentation data and damage data, which are used to anchor the hydrocode prediction methodology for varying hit points, velocities, and impact angles.

A series of 20 quarter-scale light-gas-gun impact tests were conducted at the Arnold Engineering Development Center in Tennessee in 1999 against Attitude Control Reentry Vehicle targets, and a second series of 20 shots have begun testing in FY00 against the Medium Size Reentry Vehicle, Long Range Nuclear Threat, and Attitude Control Reentry Vehicle targets. These tests employ a quarter-scale surrogate of the EKV launched against a quarter-scale replica of the target at a nominal velocity of 7 km/s. FY99 test results are described in the U.S. Army Space and Missile Defense Command Test Report.[23] A report comparing test results to hydrocode predictions, originally scheduled for publication in April 2000, is still pending.

Besides providing a backup for the hydrocode prediction methodology, the 1999 tests provided the following information:

- The damage capability of the EKV against the Attitude Control Reentry Vehicle payload for a variety of intercept conditions (two different impact velocities, five different impact angles, and various hit locations on the target).
- The sensitivity of damage level to impact velocity (two different impact velocities).
- The validity of the lethality criteria used in the NMD-capable version of PEELS for the tested intercept conditions.
- The post-impact debris characteristics.
- The sensitivity of the lethality results to different target fabrication techniques.

Additional testing is being done to improve and validate the hydrocode simulations. Sandia National Laboratory is conducting a set of high-speed impact tests using a three-stage Light Gas Gun to develop the equations of state – the characterization of the physical phenomena that occur during impact – of several aerospace materials

---

23 USASMDC, Classified *Detailed Test Report for the NMD Quarter-Scale Light Gas Gun Lethality Tests of the Exoatsmospheric Kill Vehicle Surrogate Against the Attitude Controlled Reentry Vehicle Target*, Books 1&2 (U), 15 February 2000.

present in the test targets and EKV at impact velocities of 6 km/s and 12 km/s. The materials studied are silica phenolic, E-glass, and graphite epoxy. Testing is expected to be completed later this year. If significant differences between the new empirically-derived equations of state and inputs used for the hydrocode runs are found, the hydrocode analysis will be corrected and PEELS modified accordingly. Results to date suggest that such modifications will not be necessary.

Sandia is also performing a series of hydrocode analyses for the Attitude Control Reentry Vehicle and Medium Target Reentry Vehicle targets. Their objective is to characterize the lethal volume for aerothermal structural kills. Aerothermal structural kills could occur if the target incurs sufficient damage from an EKV impact and suffers aerothermal demise during atmospheric reentry. As of March 2000, 93 hydrocode runs had been made. The analyses are expected to continue through 2000.

Based on the accumulated data from lethality tests and analyses, PEELS 8.1 was accredited by the Accreditation Working Group (AWG) on 4 April 2000. In the accreditation report dated 28 April 2000,[24] the AWG recommends accreditation of PEELS 8.1 for the following experiments:

- Determination of RV negation given the parameters that specify the RV, kill vehicle, and intercept conditions.
- Determination of Technical Performance Measures (TPMs) as specified in the Detailed Analysis Plan:
  - **TPM#23.** Probability of Single Shot Kill
  - **TPM#24.** Probability of Hitting Target within Specified Aimpoint Accuracy. Note: This TPM cannot be calculated by PEELS alone, since PEELS can only predict the probability of kill given a hit point and miss distance.
  - **TPM#25.** Probability of the NMD System Meeting its Objective.
- Determination of aimpoint selection to support DRR. However, the user should be aware of the disproportionate lethal volumes for the three targets currently modeled. Specifically, the Long Range Nuclear Threat does not contain an expanded lethal volume. In addition, the lethal volumes are expected to change in the future when late-time structural effects are included.

---

24 Joint Program Office, National Missile Defense, *The Parametric Endo/Exoatmospheric Lethality Simulation (PEELS) Accreditation Report for the National Missile Defense System (U)*, 14 April 2000, UNCLASSIFIED.

Therefore, the optimum aimpoint suggested by PEELS 8.1 may change in subsequent versions.

The accreditation report has specified the following caveats under the recommendation for accreditation approval.

- PEELS 8.1 is not suitable for the calculation of endgame maneuvers undertaken by the EKV to achieve intercept.
- PEELS 8.1 lethal volumes contain no velocity dependence.
- PEELS 8.1 provides limited probabilistic outputs. Generally, the user feeds system 6-DOF data into PEELS 8.1 for engagement-by-engagement target negation calculations and then post-processes the data to provide a complete $P_{kill/hit}$ solution.
- PEELS 8.1 does not contain all C1 threats. PEELS 8.1 only contains those threats that have been officially released by the DIA (Attitude Control Reentry Vehicle, Medium Lethality Reentry Vehicle, and Long Range Nuclear Threat).
- Because of time constraints, hydrocode runs against the Long Range Nuclear Threat have not been performed. Therefore, the expanded lethal volume used in PEELS 8.1 for the Attitude Control Reentry Vehicle and Medium Test Reentry Vehicle are disproportionate to that used for the Long Range Nuclear Threat.
- The EKV model and target models are not user changeable. Any significant change to the EKV design will require review by DOE to determine any possible changes to the lethal volume data.
- PEELS 8.1 does not calculate post-impact damage to an RV that survives impact.

Lethality Assessment

The quarter-scale Light Gas Gun testing conducted to date utilized a low fidelity surrogate of the EKV that matched the average mass properties of both the Raytheon and Boeing EKV concepts but not their precise structure or materials. The results obtained could be representative of the grosser aspects of NMD's direct hit lethality against the Attitude Control Reentry Vehicle target. The tests showed that damage to NMD targets from direct hit by the EKV will depend on the location of the impact within the payload. *Not every hit would necessarily result in a kill.*

The hydrocode analyses provided predictions of expected NMD lethality against threat targets in the hypervelocity regime and supported the development of the lethal volume in PEELS version 8.1 and enabled its use as a tool for DRR analysis.

After DRR, the development of the Live Fire Test and Evaluation (LFT&E) program will be addressed in the NMD Lethality IPT under the joint leadership of the JPO and the LSI. Although the LFT&E strategy is yet to be finalized, it is expected to include three flight tests, reduced-scale light gas gun tests, hydrocode analyses and PEELS analyses.

V. ASSESSMENT OF DEPLOYMENT READINESS CRITERIA

The NMD Joint Program Office, with OSD approval,[25] defined seven readiness criteria to measure development progress and the technical capabilities of the system. These criteria, shown in Figure V-1, are grouped into three categories, namely: *Design Development* (i.e., potential to meet ORD performance requirements), *Deployment* (i.e., ability to deploy an operational NMD system by 4QFY05), and *Program Cost.* A joint LSI-Government DRR Team is assessing/evaluating the seven criteria and will present their findings at the NMD Deployment Readiness Review. The Operational Test Agency Team will make an independent assessment of the five NMD Critical Operational Issues (COIs), which are listed in the NMD C1 TEMP, and do not directly address the seven deployment readiness criteria.

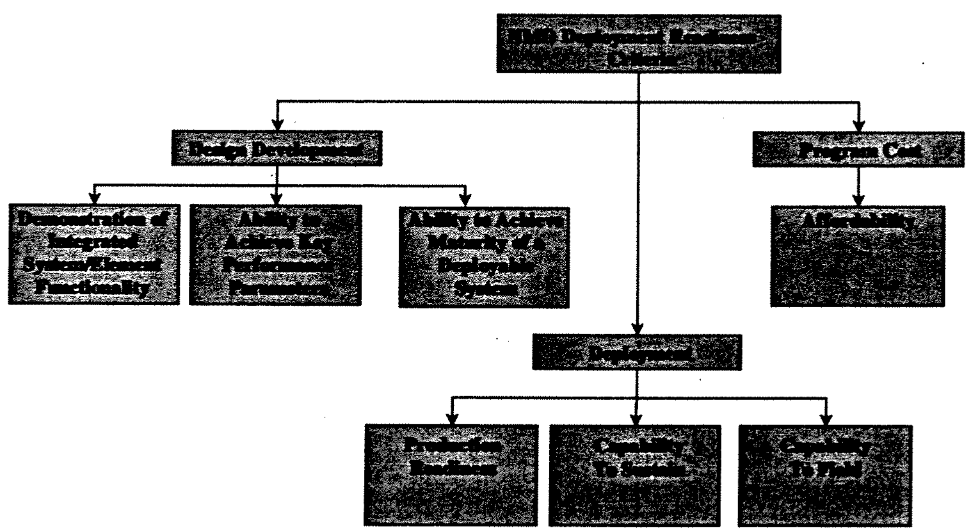

Figure V-1. Deployment Readiness Criteria

---

[25] The NMD deployment readiness criteria were approved by the Under Secretary of Defense (Acquisition & Technology) in June 1999.

Definitions of the seven criteria are given below, repeated verbatim from the LSI document, *Deployment Readiness Review (DRR) Criteria and Metrics (D742-10063-1 Rev B)*, 22 October 1999. Our assessment focuses on the effectiveness demonstrated thus far and is based upon results from Integrated Flight Tests (IFTs), Integrated Ground Tests (IGTs), exercises, and discussions with JPO officials and members of the OTA Team. We address all seven criteria, but for the Deployment and Program Cost criteria, we simply point out issues that are relevant to their assessment. The standards by which our assessment of the criteria is made are the same that we would apply to any acquisition program that is being considered for deployment.

A. DESIGN DEVELOPMENT CRITERIA (CRITERIA 1 – 3)

The three design development criteria address whether the NMD system has the potential to meet threshold operational effectiveness requirements at the time of IOC planned for FY05. An assessment is based upon ground and flight test data but requires extensive use of modeling and simulation to examine performance throughout the engagement envelope. Given the immaturity of ground testing, the delays in ground-test capabilities, the limitations of flight testing, and the inadequacy of available simulations, *a rigorous assessment of potential system performance cannot be made*. That is, no one can reliably predict that the NMD system will perform at the stressing ORD levels.

1. Criterion #1: Demonstration of Integrated System/Element Functionality

Definition: *"Demonstration of system/element level functions through integrated ground and flight testing, including two intercepts (body-to-body contact), of which one intercept must be an integrated system test (IST). To protect the FY05 IOC, a single intercept allows award of construction contracts (but not the start of construction), long haul communications, and approval of necessary long lead hardware."*

Assessment: This criterion has not been fully met since the NMD system has not achieved two intercepts nor demonstrated integrated system performance leading to a successful intercept. It did achieve an intercept in IFT-3, which allows for the award of construction contracts and long lead hardware to protect the FY05 IOC. A significant but incomplete degree of system functionality has been demonstrated over several tests.

Discussion: The LSI has identified eleven top-level NMD system functions that are to be performed by the NMD system.[26] As shown in Table V-1, seven of the eleven functions have been demonstrated to some degree in a combination of past IFTs, IGTs, Risk Reduction Flights (RRFs), and Battle Planning Exercise (BPEx) 99-5. As discussed in Chapter IV, these functional demonstrations have significant caveats associated with them, chief among them the heavy reliance on range assets and surrogate elements in IFT-3 (and in the other intercept tests, albeit to lesser extent), and the immaturity of the element representations used in IGT-4 and IGT-5.

Table V-1. Achievement of NMD System Functions

System Function	Demonstration Test Events
1. System Operations Activation	IGT-4, 5. BPEx 99-5.
2. Maintain Readiness Operation	(To be addressed after DRR)
3. System Status	IGT-4, 5. BPEx 99-5.
4. Collateral Missions	(Independent of Test Program)
5. Control of Defense	IFT-4, 5. IGT-4, 5. RRF-5, 6, 7. BPEx 99-5.
6. Integrated Engagement Planning	IFT-4, 5. IGT-4, 5. RRF-5, 6, 7. BPEx 99-5.
7. Surveillance	IFT-3, 4, 5. RRF-5, 6, 7.
8. Sensor Operations	IFT-3, 4, 5. RRF-5, 6, 7.
9. Engage	IFT-3, 4. RRF-5, 6, 7.
10. Hit/Kill Assessment	(Not demonstrated – See also Criterion 2)
11. Launch Essential Maintenance	(To be addressed after DRR)

With the exception of Kill Assessment, testing has demonstrated the basics of the seven engagement-related functions listed in Table V-1.[27] Kill Assessment has only been demonstrated in the case of a clean miss[28] and will be phased in as new space-based

26 *NMD Functional Architecture* (LSI Document Number D742-10081).

27 The seven functions are: System Status; Control of Defense; Integrated Engagement Planning; Surveillance; Sensor Operation; Engage; and, Hit/Kill Assessment.

28 Real-time kill assessment was not possible in IFT-3 because the GBR-P and BMC3 were not part of the "in-line" test.

sensors (SBIRS High) become available. The functions related to maintenance and sustainability will not be quantitatively addressed until after the DRR when prototypical system elements become available. Collateral Missions, function 4, is not evaluated in the formal test program since it serves no role in the active NMD defense of the United States.

The eleven functions defined by the JPO do not specifically single out discrimination as one of the "system functions," although it clearly is involved in "engagement planning," "sensor operations," and the "engage" function. Given the technical challenge posed by discrimination, subsuming it at a lower level is inadvisable. Using its IR sensors and on-board processing, the EKV did distinguish the MRV from a large balloon and deployment bus in IFT-3. However, not only did the balloon and bus have IR signatures very different from the MRV, the EKV contractor was provided with detailed information about the target suite – required to execute the discrimination algorithm – before the flight test was performed.[29] The ability to function in a challenging – but still unsophisticated – countermeasure environment has not yet been demonstrated. Also, the simulations in ground tests have not convincingly demonstrated system functionality in a multiple target environment.

IFT-4 did show that the GBR-P could discriminate the MRV from tank-like objects, the large balloon, and debris. In addition, IFT-5 demonstrated that the GBR-P could discriminate the MRV from tank-like objects and debris. However, the target suites in the intercept flight tests did not include objects with radar signatures designed to mimic those of the MRV.

The Vandenberg-Kwajalein test geometry with the GBR-P radar essentially co-located with the interceptor limits the realism with which integration of the elements can be demonstrated. The Upgraded Early Warning Radar (UEWR) surrogate in California cannot replicate the role of an UEWR since it can acquire the target almost immediately after launch and is looking at a receding target at short range. The GBR-P on Kwajalein is limited by power and radar horizon from acquiring and discriminating the target early enough to be the source of Weapon Task Plan data. The test geometry forces the reliance on external, non-system assets such as GPS or the FPQ-14 range radar to provide data to support engagement planning.

29 Balloons with IR signatures matched to the RV being flown will not be used until IFT- 10; there are no plans as yet to withhold detailed information about target signatures in an intercept test.

2. Criterion #2: Ability of the System Design to Meet Key Performance Parameters

Definition: *"An assessment of the ability of NMD system design to meet system performance requirements as specified in the NMD Operational Requirements Document (ORD), including a plan to resolve shortfalls in the design, if required."*

Assessment: The NMD system has demonstrated satisfactory progress in meeting two of the four required KPPs, namely, Human-in-Control and automated BMC3. Demonstration of the interoperability KPP has not yet begun. The system's ability to defend all fifty states from attacks at ORD-specified levels (KPP #1) has not been satisfactorily assessed, primarily because the simulations that were to demonstrate this with confidence and high fidelity have not matured as planned. Assessing KPP #4 (Interoperability) is not part of the LSI evaluation plan for the DRR. However, the OTA Team and DOT&E will evaluate KPP #4 as part of the continuing evaluation of NMD.

Discussion: A Key Performance Parameter (KPP) is that capability or characteristic so significant that failure to meet the threshold value can lead to the reassessment or termination of the program. The latest (June 2000) NMD ORD identifies four KPPs:

- KPP #1 – Defense of the United States. The ability of the system design to meet threshold operational effectiveness requirements – negation and performance probabilities – given a specific attack size and sophistication of associated countermeasures.
- KPP #2 – Human-in-Control (HIC). The capability of the system for positive control of the NMD system by human operators for system functions such as battle redirection, weapon release, and engagement termination.
- KPP #3 – Automated BMC3. The ability of the system to provide automated battle management capability.
- KPP #4 – Interoperability. The ability of the system to be interoperable and compatible with external systems such as ITW/AA and NORAD. The operational benefit of interoperability will be enhanced flexibility enabling the addition of new users or new missions and optimized information flow.

Criterion 2 focuses on the ability of the system design to meet ORD specified requirements in key areas. However, as indicated above, the immaturity of ground testing and the inadequacy of available simulations preclude evaluators from making a rigorous assessment of potential system performance. One example is the current limited ability to conduct nuclear survivability testing of the EKV to the required flux levels. Additionally, IGTs did not incorporate nuclear environment effects in the design-to scenarios. Neither the DRR Team nor the OTA Team can reliably predict that the NMD system will perform at the ORD levels.

LIDS, the principal M&S tool to have been used by the OTA Team to evaluate NMD system performance, was not available in time to support the DRR. Furthermore, the LIDS version that was delivered has the following limitations that may preclude it from being accredited in the future as a valid evaluation tool.

- LIDS emulates BMC3 operations in an unrealistic, low-fidelity manner.
- Radar models within LIDS are represented as "cookie cutters." The representations are relatively simplistic and are specification-based rather than physics-based.
- LIDS does not have much flexibility with regards to operator control of engagement conditions.

The Integrated System Test Capability (ISTC) hardware and software used in the IGTs to date are immature and do not provide an adequate representation of the NMD C1 architecture. None of the major NMD elements (BMC3, XBR, UEWR, Weapon System, and DSP/SBIRS) are mature enough to provide an adequate performance evaluation of the NMD C1 system. IGT-4 and IGT-5 did demonstrate the integration of the BMC3 with the UEWR and XBR, but these tests provide only limited data to support an evaluation of the proposed NMD C1 system at the DRR. Major shortcomings in IGT-4 and IGT-5 that hamper the evaluation of the system to meet its Key Performance Parameters include the following limitations:

- Weapon System
  - No position or velocity errors in GBI/EKV flyout
  - IFTU/TOM not used by EKV
  - IFICS communications event windows are ignored
  - No raid sizes greater than one using the high fidelity representations of the EKV (RTSim)
  - Larger raid sizes not assessable because weapon system test drivers lack high enough fidelity
  - Limited number of interceptors available
  - No valid representation of command and launch equipment
  - No RTSim V&V information available to OTAs or DOT&E; fidelity of RTSim model is unknown

- EKV acquisitions of targets are unrealistically optimistic due to low noise assumptions

- DSP/SBIRS Simulation
  - Timing and transmission of threat launch alert messages are scripted and not indicative of actual DSP or SBIRS performance
  - DSP/SBIRS booster burn out messages are near perfect, so radar detections based on these cues are unrealistic
- Radars Simulation
  - UEWR Simulation does not support discrimination or classification, and therefore cannot identify threat RVs

While ground testing isn't adequate for reliably predicting system performance at IOC, it has raised significant issues that call into question the ability of the NMD system to negate threats at the ORD levels. Each KPP entails issues that are not fully resolved by the time of the DRR:

- KPP #1 – Defense of the United States.
  - SBIRS High for NMD utilization (at least three satellites) is not expected to be available until 2006. Therefore, cueing of NMD radars will continue to rely on DSP. SBIRS High unavailability will also degrade kill assessment capabilities.
  - Even if SBIRS High is available and meets its own ORD requirements for target position and velocity, the OTA Team has indicated that SBIRS High might not be accurate enough to enable the XBR to acquire the target complex. This is particularly problematic when the "blind time" between booster burnout and XBR acquisition of the missile complex is long.[30]
  - UEWR participation in RV detection, tracking, and classification is absolutely essential in dealing with ICBM threats to the East Coast of CONUS. The OTA Team has raised system architecture issues on the limitations of UEWR coverage to deal with some of these threats. Also, it is not clear that the UEWRs will have the detection and classification performance necessary to negate all the C1 threats to the 50 United States.
  - The uncertainty in predicted impact points near but within the boundary of the protected area, as determined by the battle-management software, may result in the failure to engage the threat. Similarly, predicted impact points near but outside the boundary of the protected area may result in the unnecessary launch of interceptors.

---

30 The uncertainty in target position grows linearly with time.

- The JPO has determined that the CAIV estimate for meeting the reliability requirements for long-haul communications is currently unaffordable. The User community has, therefore, deferred full satisfaction of these requirements at this time. Thus, the ability of the NMD system to meet reliability requirements will not be met at IOC but will be eventually phased in.

- KPP #2 – Human-in-Control (HIC). The HIC requirements will likely be achieved by the time of IOC.
  - To date, C2Sim's and BPEx's have demonstrated all three HIC actions, namely, "Granting Defense Engagement Authorization (DEA)," "Management by Exception," and "DEA Withdraw."
  - However, BPEx's have shown that situation awareness is degraded because of the phenomenon of "phantom tracks." Phantom tracks arise when radar coverage of a tracked RV transitions from one radar to a second (known as "handover"), and the BMC3 mistakenly interprets the new radar returns as originating from a second RV. BPEx 99-5 runs have demonstrated that this phenomenon occurs with sufficient frequency that operator control of the NMD system is adversely impacted.

- KPP #3 – Automated BMC3. The automated BMC3 requirements will likely be achieved by the time of IOC.
  - To date, C2Sim's and BPEx's have demonstrated the ability of the BMC3 to provide automated decision support. An unresolved issue pertaining to automated BMC3 is the timeliness of integrated engagement planning, and in particular, the inability of the battle manager to meet required time constraints for certain scenarios.
  - An issue of resource management was uncovered during BPEx 99-5. Operators were unable to prevent interceptors from being launched at phantom RVs by employing Management by Exception. Rather, they were forced to put interceptors in reserve mode.

- KPP #4 – Interoperability. The approved ORD of January 1997 had only KPPs 1 – 3. The addition of the interoperability KPP was raised in 1999 but was not formally added until the new June 2000 ORD was approved. Assessing interoperability was not part of the LSI evaluation plan for the DRR. The NMD system is not yet mature enough to fully assess interoperability.
  - The NMD Communications architecture is not yet finalized. The OTA Team warns that, as a result, the system might not be ready to support IOT&E.

- The BMC3 to Commander-In-Chief (CINC) interface inside Cheyenne Mountain will not be tested prior to the DRR, and the User has not yet approved a plan for this integration.

3. Criterion #3: Maturity of the Deployable System Design

Definition: *"An assessment of the readiness of the system design to be manufactured, deployed, supported, and potentially evolved to counter more sophisticated threats."*

Assessment: Design reviews have not identified any significant issues pertaining to the maturity of the design of the NMD system or elements. However, the ability to perform a credible assessment of NMD design maturity is confounded by the current immature state of ground test facilities and models and simulations. Furthermore, the JPO has not yet developed a formal, credible plan for evolving the design from C1 to C2/C3. In particular, the ability to discriminate more sophisticated countermeasures needs special consideration. Discrimination is a high-risk area that if left unresolved could prevent NMD from meeting its requirements.

Discussion: The EKV and XBR are being designed to counter the C2 threat, and the BMC3 has an internal architecture suitable for evolution. However, these are all theoretical assessments. We are unaware of any testing that verifies these assessments and, thus, have serious concerns with the evolution of the C1 architecture to C2 and C3 architectures.

- Discrimination is perhaps the most challenging aspect of national missile defense. As discussed extensively in open literature, the enemy could employ various types of countermeasures to overwhelm this function. Furthermore, onboard discrimination relies heavily on *a priori* threat information derived from intelligence sources. In short, there has not been any demonstration that the discrimination algorithms are sufficiently robust for handling unexpected sophisticated countermeasures in realistic scenarios.
- SBIRS Low is an integral component of the NMD C3 (objective) system, necessary for performing midcourse tracking and discrimination in many operational engagements. A preliminary System Requirements Review recently held in July 2000 indicated that SBIRS Low might not adequately augment NMD system discrimination capability.

A 1992 Defense Science Board (DSB) report[31] on ballistic missile defense underscores our concerns on discrimination. Not only does the report speak of the unpredictability of the actions of "Third World Aggressors" with regards to their employment of penetration aids. The DSB panel makes the following recommendation: "The US response to the problem of PENAIDS should be a highly focused intelligence effort and a substantial testing program in which flexible and robust radar and interceptor techniques can be developed and proven against a wide variety of simple PENAIDS and tactics." The findings and recommendations of this report remain valid today.

B. DEPLOYMENT CRITERIA (CRITERIA 4 – 6)

The three criteria under deployment – production readiness, capability to sustain, and capability to field – were selected to demonstrate that all necessary planning functions have been completed with enough detail at the time of DRR to allow for the production and deployment of an operationally suitable and sustainable system by 2005.

1. Criterion #4: NMD Production Readiness

Definition: *"An assessment of the program's readiness to produce the system."*

Assessment: While there is no direct data to support findings in this area, it is apparent from difficulties in maintaining flight test schedules that the extreme quality control that must be maintained in assembly and preparation of the EKV will complicate the weapon system production process.

Discussion: This criterion is an assessment of the NMD program's readiness to produce the components of the NMD system – with the quality and reliability necessary to meet the NMD program requirements – on time to support a FY05 deployment in accordance with the phased production program and required DAB milestones. A production readiness assessment will be based on system and element manufacturing and producibility plans.

2. Criterion #5: Capability to Field the NMD System

Definition: *"An assessment of the program's readiness to field the system."*

---

31 *Report of the Defense Science Board Task Force on Ballistic Missile Defense (U)*, 1991 Summer Study, SECRET.

Assessment: As stated in the Criterion #4 assessment above, the quality control requirements in assembling the EKV will probably drive the weapon system production timelines. Past experience in preparation for integrated flight testing suggests that this may have a major impact in satisfying the FY 05 and 07 delivery requirements. The LSI states that it is "aware of no evidence" that quality control is an issue.

Discussion: This criterion is an assessment of the NMD program's readiness to field the system. In order to support site selection and a construction award, deployment functions such as facility/site design and environmental impact statements must be complete. The DRR Team has indicated that tactical and tactical support facility designs[32] will not be at the required 100 percent completion by the DRR date. Long-lead times required for construction and environmental work make progress in this area especially critical in order to meet the deployment schedule.

3. Criterion #6: Capability to Sustain the NMD System

Definition: *"An assessment of the program's readiness to sustain the system once fielded."*

Assessment: Insufficient data available to make an assessment. The OTA assessment is expected to address survivability aspects of the program in their Early Operational Assessment (EOA) report.

Discussion: This criterion is an assessment of the NMD program's readiness to sustain the system once fielded. An evaluation will be made based on progress toward the development or completion of the following items:

- JPO-generated documents
  - Joint Manpower Estimate (JME)
- LSI-generated documents:
  - Integrated Logistics Support Plan (ILSP)
  - System Training Plan (STP)
  - Operational Suitability Assessment Report
- OTA assessment

---

32 Tactical facilities are those needed to meet the operating requirements of the NMD system, including the XBR antenna mount facility, radar control and support systems facility, launch farm complex, missile field, readiness station, interceptor receiving and processing facility, interceptor storage facilities, and maintenance and vehicle heated storage facility.

- Early Operational Assessment

C. PROGRAM COST CRITERION (CRITERION 7)

Definition: "An estimate of the total system acquisition, sustainment, and disposal cost."

Assessment: The total cost of the Capability 1 NMD system was assessed by the United States General Accounting Office at $36.2B.[33] There are still several cost uncertainties in the T&E arena that the Department needs to address that could drive the cost higher. Removal of the limitations to operational realism will have to be factored into the overall program cost.

Discussion: A cost assessment includes a comprehensive review and comparison of program information from a variety of sources. The following items must be evaluated:

- Funding assessment.
- A Program Life-Cycle Cost Estimate (PLCCE) of the NMD C1 program reconciled with the BMDO NMD cost assessment.
- A review of CAIV Trades and Cost Targets assessments.

An Independent Cost Estimate (ICE) of NMD Program Life-Cycle Cost performed by the Cost Analysis Improvement Group (CAIG).

---

33 Refer to GAO Report GAO/NSIAD-00-131, *Status of the National Missile Defense Program*, May 2000.

VI. RECOMMENDATIONS

A. FLIGHT TESTING

1. Testing Complexity

Testing is currently designed to accommodate an aggressive pace of development. Flight testing, however, needs to aggressively increase in complexity to keep pace with NMD C1 development and to adequately stress design limits, particularly for the missile system.

- Target suites used in integrated flight tests need to incorporate challenging unsophisticated countermeasures that have the potential to be used against the NMD C1 system (e.g., tumbling RVs and non-spherical balloons). Use of the large balloon should be discontinued, as it does not mimic in any way the current test RV. True decoys that attempt to replicate RV signatures as well as balloon-type countermeasures that have been examined by the Countermeasures Hands-On Program (CHOP) need to be integrated into flight test target suites.
- Engagement times of day and solar position need to be planned to stress the acquisition and discrimination process by all of the sensor bands. Additionally, the effects of weather on radar, telemetry and satellite operations need to be tested either during intercept or risk reduction flight tests or other targets of opportunity. Radar discrimination, IFICS transmission/reception, and DSP/SBIRS launch detection may be operating at their technical limits, and heavy rain or dense cloud conditions may have significant effects on their performance.
- Category B engagements are engagements in which an interceptor is launched against a target cluster (based on radar track) before the threat RV is resolved and discriminated. Since such engagements are expected to be common during NMD missions, this capability will need to be demonstrated in an integrated flight test before IOC. Such engagements are currently not included in the defined test plan.
- Multiple engagements will be the expected norm in tactical situations, therefore, simulated extrapolation from 1-on-1 scenarios to M-on-N need to

be validated through intercept flight testing. Multiple engagements of at least 2-on-2 scenarios need to be flight tested, as too many technical challenges to the system exist beyond merely the command and control software. Identifying the impact of the interaction of one kill vehicle to another and assessing the performance of ground tracking systems in M-on-N scenarios lead to several questions:

- How will an EKV respond to another EKV in its field of view, or multiple RVs in its field of view?
- How is the performance of an EKV seeker affected by a thrusting EKV or another EKV intercepting an object in its field of view?
- Can the X-Band radar simultaneously track multiple RVs that require different antenna orientations?
- Can the IFICS communicate with multiple KVs?

- Radar discrimination with limited *a priori* knowledge of the target complex needs to be flight tested prior to the FY01 radar decision. This type of test ("pop quiz" type) of flight test needs to be executed, at least during a risk reduction flight. This test should employ multiple decoys designed to mimic the RV radar signature but should not provide unrealistically detailed target or decoy information to the GBR-P radar prior to the engagement.

2. Testing Artificiality

Current test range limitations need to be removed to adequately test the NMD system.

- Use of the FPQ-14 range radar as the source of Weapon Task Plan data needs to be phased out. Target trajectories or radar surrogate locations need to be changed to permit the organic NMD system to provide early radar cueing with the appropriate degree of position and velocity accuracy.
- Engagement geometries need to be devised that will provide higher speed engagement conditions for the EKV, as would be expected in the C1 timeframe with the tactical booster.

3. Operational Realism

Avoidable limitations to operational realism must be removed before conduct of IOT&E.

- Rehearsed engagements with *a priori* knowledge of target complex, target trajectory, and time of launch need to be discontinued during operational testing. Situations employing lack of *a priori* knowledge also need to be examined in DT to assure acquisition and discrimination algorithms are properly designed.

- The flight testing artificialities addressed above must be eliminated for IOT&E. Alternative intercept test scenarios must be devised that employ inbound or crossing targets rather than outbound relative to the Early Warning Radar. GPS and midcourse radar tracking using a transponder cannot be used by the NMD system to perform its mission. The Weapon Task Plan must be prepared based on organic NMD tracking systems. Option for higher speed intercepts must be investigated.
- Deployed element usage needs to be maximized for IOT&E. The X-Band Radar and/or Upgraded Early Warning Radar should be used. Deployed IFICS ground antennas and tactical communications should also be tested as part of the IOT&E.
- Multiple engagements must be accomplished during IOT&E. Furthermore, this type of engagement should be flown in IFTs before IOT&E to maximize the chance of success in IOT&E.

4. Spares

Plans for providing adequate spares should be developed, especially for targets where current target components can be as much as 30 years old.

- Adequate GBI booster spares need to be procured as a risk reduction effort, to preclude further schedule slip should a failure occur in preflight booster testing.
- NMD is currently employing what is referred to as a "rolling spare" concept for its targets. It can take up to six weeks to prepare for and reset the IFT launch date. A "hot spare" approach for which an additional target is prepared at the target launch site would eliminate the need to stand down operations at the interceptor launch site in the event of a failed target launch. This could be more significant as flight testing becomes more complex or critical, such as in the small number of OT shots, when a failed target launch might be much more costly to the program. The delay to the target launch during IFT-5 is a strong example of this potential problem. If the last minute target problems could not have been corrected, IFT-5 would have slipped an additional month.

B. GROUND TESTING AND SIMULATION

1. Hardware-in-the-Loop (HWIL)

An innovative new approach needs to be taken towards HWIL testing of the EKV, so that potential design problems or discrimination challenges can be wrung out on the ground in lieu of expensive flight tests.

- HWIL development needs to focus on the EKV, since this is the most challenging technical area for NMD hit-to-kill. Funding and development needs to be accelerated or the required capability in this area will not be available to support C1 testing.
- The HWIL facility and test approach needs to be done at the highest level of EKV system integration achievable, so that all component interaction, from sensors to the divert systems, can be examined simultaneously.
- An innovative approach should be taken that provides an interactive scene generation capability that adapts to changes in EKV and target aspect angles.
- Scene generation should have the capability to challenge target acquisition by the EKV, discrimination and homing algorithms with anticipated or potential countermeasures.

2. Lethality

Current analysis of exoatmospheric lethality is limited to computer simulations and light gas gun tests.

- New techniques or facilities need to be developed to achieve higher speed intercepts on the ground in full scale to validate hydrocode simulations and ¼ scale light gas gun tests.
- Investments need to be made in the Holloman High Speed Test Track to permit lethality testing of medium to high fidelity representations of the kill vehicle to at least the low end of the range of potential intercept velocities.

3. Simulation

LIDS development has taken much longer than originally promised. Additionally, it is practically a hard-wired simulation that only the Boeing developers can modify. This precludes independent, Government sensitivity analysis and assessment.

- LIDS needs to evolve to a fully validated high fidelity simulation. It should be flexible enough to allow both DOT&E and Service Operational Test Agencies to examine subsystem drop-outs and graceful degradation or other areas of sensitivity or design margin analysis. There is currently no apparent plan by the LSI to do this.

C. PROGRAMMATIC ISSUES

1. Performance Criteria

Discrimination by the radar and weapon system (EKV) should be given more weight in performance criteria. All other aspects of the NMD performance requirements appear to be within the state of the art of technology. Discrimination by the EKV on the other hand will be the biggest challenge to achieving a hit-to-kill intercept. Decoys that provide a close representation of the RV or modify the RV signature have only been minimally investigated.

2. ORD Reliability Requirements

The NMD requirements for reliability, availability, and effectiveness are specified in the NMD ORD. When these requirements are allocated to the individual elements of the NMD system, the resulting reliability performance standards are unrealistically high as well as difficult to test. As the program develops, it may be necessary to re-examine the overall requirements for NMD reliability and availability.

3. Risk Reduction Efforts

The following programs can make significant contributions to risk reduction efforts if properly utilized.

- Minuteman Missile OPEVAL testing needs to continue to be leveraged, not only for IFT rehearsal, but also to look at the impact of countermeasures to ground radar systems.
- Ballistic Missile Critical Measurements Program tests need to be conducted to examine countermeasure signatures and discrimination algorithms.

4. Countermeasures Hands-On Program (CHOP)

BMDO sponsors a red team approach to the possible development of countermeasures. Operated at very modest funding levels, CHOP develops and demonstrates ROW countermeasures that could be challenging for U.S. missile defense systems. By charter, CHOP does not try to develop "sophisticated" countermeasures. However, the unsophisticated, ROW countermeasures they do develop are realistic and challenging and should be included as an integral part of the NMD flight testing and ground test HWIL simulation programs.

- The CHOP program needs to be supported for aggressively examining the potential of states of concern to develop more sophisticated countermeasures.
- The Defense Intelligence Agency (DIA) needs to begin tracking CHOP experiments. They should then investigate and bound the ability of states of concern to develop and apply the technologies that the CHOP teams use in their experiments to counter an NMD system. This information should then be fed back to CHOP management for planning and executing CHOP developments.

5. Operations in a Nuclear Environment (OPINE)

The NMD Program Office chartered a red team to look at OPINE testing and facility requirements for the EKV. The red team found the Raytheon-proposed test and parts screening program to be inadequate.

- OPINE testing needs to be conducted at the EKV system level in nuclear environments that replicate expected operational conditions, including expected flux levels.
- OPINE test facilities at Aberdeen Proving Ground and Arnold Engineering Development Center need to receive appropriate and timely funding to support EKV OPINE testing required to begin in FY02.

6. Hit to Kill

The NMD Program Office should investigate lethality enhancement options for dealing with potential countermeasures, using relatively simple techniques, that try to alter the effective RV size or shape in an attempt to foil discrimination and aimpoint selection.

APPENDIX A – CROSSWALK

The U.S. Army Test and Evaluation Command (ATEC), the U.S. Air Force Operational Test and Evaluation Center (AFOTEC), and the Joint Interoperability Test Command (JITC), acting as an Operational Test Agency (OTA) team, are addressing NMD system operational effectiveness and suitability for the DRR. The OTA team results will be recorded in the Early Operational Assessment (EOA) report and presented in briefing format at the DRR. Rather than evaluating the seven DRR criteria, as is being done by the LSI-JPO DRR team, the OTA Team is focusing on the Critical Operational Issues (COIs)[34], listed below, to address system effectiveness and suitability.

- COI-1 (Negate Threat): Does the NMD System have the ability to detect, discriminate, engage, intercept, and negate the threat to defend the 50 United States?
- COI-2 (Battle Management/Decision Support): Does the NMD System generate and provide the required Human-in-Control and automated battle management decision support to ensure the system responds in a way consistent with operational requirements?
- COI-3 (Interoperability/Graceful Degradation): Does the NMD System allow for interoperability and integration with existing and planned systems, in accordance with joint standards, to provide for effective mission performance, to include graceful system degradation?
- COI-4 (System Supportability): Does the NMD System supportability and operational availability provide for continuous operations through each phase of the system's lifecycle?
- COI-5 (Survivability/Security): Is the NMD System survivable and secure in expected operational environments?

Table A-1 depicts the relationship between COIs, Key Performance Parameters (KPPs), and the DRR criteria.[35] As indicated in Table A-1, the COIs do not readily map into the DRR criteria. Indeed, the DRR criteria were generated to answer whether an

---

[34] The COIs, which are derived from the NMD ORD and developed by USSPACECOM, are documented in Part IV of the NMD TEMP.

[35] Refer to Chapter III, "Deployment Readiness Review," for complete definitions of the KPPs and deployment criteria.

effective NMD system could be deployed by FY05, whereas the COIs address effectiveness and suitability issues, *given a deployed system*, during Operational Test and Evaluation (OT&E). The five COIs overlap primarily with the Design Development Criteria (Criteria 1 – 3) as well as Criterion 6 (Capability to Sustain the NMD System).

Table A-1. COI, KPP, DRR Criteria Crosswalk

Critical Operational Issue	Key Performance Parameter	DRR Criteria
COI-1 (Negate Threat). Does the NMD System have the ability to detect, discriminate, engage, intercept, and negate the threat to defend the 50 United States?	KPP 1 (Defense of the US).	Criterion 1 (Demonstration of System/Element Functionality). Criterion 2 (Meeting KPPs). Criterion 3 (Maturity of System Design).
COI-2 (Battle Management/ Decision Support). Does the NMD System generate and provide the required Human-in-Control and automated battle management decision support to ensure the system responds in a way consistent with operational requirements?	KPP 2 (Human-in-Control). KPP 3 (Automated BMC3).	Criterion 1 (Demonstration of System/Element Functionality). Criterion 2 (Meeting KPPs).
COI-3 (Interoperability/ Graceful Degradation). Does the NMD System allow for interoperability and integration with existing and planned systems, in accordance with joint standards, to provide for effective mission performance, to include graceful system degradation?	KPP 4 (Interoperability).	Criterion 1 (Demonstration of System/Element Functionality). Criterion 2 (Meeting KPPs). Criterion 3 (Maturity of System Design).
COI-4 (System Supportability). Does the NMD System supportability and operational availability provide for continuous operations through each phase of the system's lifecycle?	KPP 4 (Interoperability).	Criterion 2 (Meeting KPPs). Criterion 6 (Capability to Sustain the System).
COI-5 (Survivability/Security). Is the NMD System survivable and secure in expected operational environments?	KPP 1 (Defense of the US). KPP 4 (Interoperability).	Criterion 2 (Meeting KPPs). Criterion 6 (Capability to Sustain the System).

APPENDIX B – DATA SOURCES

The following test execution reports, documents, briefings, etc. were referenced in the writing of the DOT&E DRR Report.

INTEGRATED FLIGHT TESTS

IFT-1A

- *Sensor Flight Test Final (60 Day) Report, Addendum 1 – Classified Data and Results*, 24 June 1997, BOEING COMPETITION SENSITIVE (SECRET)
- *National Missile Defense (NMD) Integrated Flight Test 1A (IFT-1A) Test Execution Report*, 31 August 1997, BOEING COMPETITION SENSITIVE
- *Integrated Flight Test 1A Post-Test Analysis Report (PTAR) for the National Missile Defense System*, 10 September 1997 (SECRET)
- *IFT-1A Final Integrated Truth Data Package*, 15 September 1997 (SECRET)

IFT-2

- *IFT-2 Sensor Flight Test Final Report*, 6 April 1998, RAYTHEON COMPETITION SENSITIVE (SECRET)
- *National Missile Defense Integrated Flight Test 2 Test Execution Report*, 27 March 1998, RAYTHEON COMPETITION SENSITIVE
- *National Missile Defense (NMD) Final Post Test Analysis Report Integrated Flight Test (IFT) 2*, 28 May 1998 (SECRET)
- *IFT-2 Final Integrated Truth Data Package*, 16 March 1998, (SECRET)
- IFT-2 Post Mission Data Review Presentation Package, 26 March 1998

IFT-3

- IFT-3 Quick Look Data Review Briefing, 7 October 1999
- IFT-3 Post Test Analysis Briefing, 18-19 November 1999
- *IFT-3 60-Day Integrated Data Package Report*, 3 December 1999 (SECRET)
- *IFT-3 Test Evaluation Report*, 21 January 2000, RAYTHEON COMPETITION SENSITIVE (SECRET)

- NMD OTA IFT-3 Level III Authenticated Database, 1 March 2000, 1 CD-ROM (SECRET)

IFT-4

- Integrated Flight Test 4 Initial Results Briefing, 28 January 2000
- IFT-4 Post Test Analysis Briefing, 22 March 2000
- NMD OTA IFT-4 Level III Authenticated Database, 4 April 2000, 1 CD-ROM (SECRET)

IFT-5

- *NMD Integrated System Test 5 48-Hour Report*, 10 July 2000

INTEGRATED GROUND TESTS

IGT-3

- *Integrated Ground Test Three (IGT-3) Quick Look Report (QLR)*, 22 February 1999

IGT-4

- *Integrated Ground Test Four (IGT-4) Quick Look Report (QLR)*, 20 August 1999
- *IGT-4 Test Evaluation Report*, 3 November 1999 (SECRET)
- NMD OTA IGT-4 Level III Authenticated Database, 13 December 1999, 5 CD-ROMs (SECRET)
- NMD OTA IGT-4 Frame-grabber Data, 28 December 1999 (SECRET)

IGT-5

- *IGT-5 Test Evaluation Report*, 23 December 1999 (SECRET)
- NMD OTA IGT-5 Frame-grabber Data, 28 December 1999 (SECRET)
- NMD OTA IGT-5 Level III Authenticated Database, 8 March 2000, 7 CD-ROMs (SECRET)

RISK REDUCTION FLIGHTS

- *National Missile Defense Lead System Integrator Risk Reduction Flight 5 Post Test Report*, 19 April 1999

- *National Missile Defense Lead System Integrator Risk Reduction Flight 7 48 Hour Assessment Report*, 15 November 1999
- NMD OTA RRF-6 Level III Authenticated Databases, 28 March 2000, 1 CD-ROM (SECRET)

BATTLE PLANNING EXERCISES

- *National Missile Defense (NMD) Battle Planning Exercise (BPEx) 99-1 Final Report*, 24 March 1999
- *National Missile Defense (NMD) Battle Planning Exercise (BPEx) 99-2 Final Report*, 4 August 1999
- *National Missile Defense (NMD) Battle Planning Exercise (BPEx) 99-3 Final Report*, 25 August 1999
- *National Missile Defense Early Operational Assessment Battle Planning Exercise 99-5 After Action Report*, 7 December 1999

EXTERNAL ASSESSMENTS

- NMD OTA Team Interim Early Operational Assessment I Briefing, 15 February 2000

DATA SOURCES – PENDING

Integrated Flight Tests

- IFT-4 Test Evaluation Report
- IFT-4 Integrated Data Package Report
- IFT-5 Test Evaluation Report
- IFT-5 Integrated Data Package Report
- NMD OTA IFT-5 Level III Authenticated Database

Risk Reduction Flights

- RRF-6 Post Test Report
- RRF-7 Post Test Report

APPENDIX C – ACRONMYS

ABM	Anti-Ballistic Missile
AFOTEC	Air Force Operational Test and Evaluation Center
ATEC	Army Test and Evaluation Command
AWG	Accreditation Working Group
BI-1	Build Increment 1
BMC2	Battle Management, Command, and Control
BMC3	Battle Management Command, Control, and Communications
BMD	Ballistic Missile Defense
BMDO	Ballistic Missile Defense Organization
BPEx	Battle Planning Exercise
C1	Capability 1
C2Sim	Command and Control Simulation
CAIG	Cost Analysis Improvement Group
CAIV	Cost as an Independent Variable
CHOP	Countermeasures Hands-On Program
CI-3A	Capability Increment 3A
CINC	Commander-In-Chief
COE	Common Operating Environment
COI	Critical Operational Issue
CONUS	Contiguous United States
COTS	Commercial Off The Self
DAB	Defense Acquisition Board
DEA	Defense Engagement Authorization
DIA	Defense Intelligence Agency
DII	Defense Information Infrastructure
DoD	Department of Defense
DOT&E	Director, Operational Test and Evaluation
DRR	Deployment Readiness Review

DSB	Defense Science Board
DSP	Defense Support Program
EKV	Exoatmospheric Kill Vehicle
EOA	Early Operational Assessment
FY	Fiscal Year
GBI	Ground Based Interceptor
GBR-P	Ground Based Radar-Prototype
GN&C	Guidance, Navigation, and Control
GPS	Global Positioning System
HIC	Human-in-Control
HTK	Hit to Kill
HW	Hardware
HWIL	Hardware in the Loop
ICBM	Inter-Continental Ballistic Missile
ICE	Independent Cost Estimate
IFICS	In-Flight Interceptor Communications System
IFT	Integrated Flight Test
IFTU	In Flight Target Update
IGT	Integrated Ground Test
ILSP	Integrated Logistics Support Plan
IMU	Inertial Measurement Unit
IOC	Initial Operational Capability
IOT&E	Initial Operational Test and Evaluation
IR	Infrared
IST	Integrated System Test
ISTC	Integrated System Test Capability
ITW/AA	Integrated Tactical Warning / Attack Assessment
JITC	Joint Interoperability Test Command
JME	Joint Manpower Estimate
JNTF	Joint National Test Facility
JPO	Joint Program Office
JTA	Joint Technical Architecture
KLC	Kodiak Launch Complex

KMR	Kwajalein Missile Range
KPP	Key Performance Parameter
LFT&E	Live Fire Test and Evaluation
LGG	Light Gas Gun
LIDS	LSI Integration Distributed Simulation
LSI	Lead System Integrator
MDAP	Major Defense Acquisition Program
MBE	Management-by-Exception
MRV	Medium Reentry Vehicle
MSE	Multiple Simultaneous Engagement
NCA	National Command Authority
NMD	National Missile Defense
OPINE	Operations in a Nuclear Environment
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OTA	Operational Test Agency
OT&E	Operational Test and Evaluation
PEELS	Parametric Endo-Exoatmospheric Lethality Simulation
PLCCE	Program Life-Cycle Cost Estimate
PLV	Payload Launch Vehicle
ROW	Rest-of-World
RRF	Risk Reduction Flight
RTC	Report to Congress
RTSim	Real-Time Simulation
RV	Reentry Vehicle
SBIRS	Space Based Infrared System
STP	System Training Plan
SW	Software
TD 2	Taepo Dong 2
TEMP	Test and Evaluation Master Plan
TPM	Technical Performance Measure
UEWR	Upgraded Early Warning Radar
UHF	Ultra-High Frequency

USSPACECOM	US Space Command
VAFB	Vandenberg Air Force Base
WTP	Weapon Task Plan
XBR	X-Band Radar